MAY 24 1923

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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See Advertisement page 66, May 4. 2402

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and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

TENDERS.

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to noon on Wednesday, 30th May,

Tenders for the Supply of :—

1. LAMINATED SPRINGS,
2. HELICAL or VOLUTE SPRINGS,
3. STEEL TYRES for Locomotives,
4. CRANK AND STRAIGHT AXLES for Locomotives.

Tenders must be made on Forms, copies of which, with Specification, can be obtained at these Offices, on payment of 20s. each (which will Not be returned).

The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG,
Secretary.

Offices: 91, Petty France, Westminster, S.W. 1.
8th May, 1923. A 472

ADMINISTRATIVE COUNTY OF LONDON.

The London County Council invites

Tenders for a New Cornish

BOILER (with fittings) for Culloden Street School, Poplar, 30 ft. 14; the boiler to be 6 ft. diameter by 18 ft long.

Persons desiring to Tender may obtain on and after Monday, 14th May, 1923, the drawings, specification, form of Tender, etc., on application to the Chief Engineer at the Old County Hall, Spring Gardens, S.W. 1., upon payment of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Full Particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected at the Old County Hall before payment of the fee.

No Tender received by the Clerk of the Council at the Council Hall, Westminster Bridge, S.E. 1, after Four p.m. on Monday, 28th May, 1923, will be considered,

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 422

COUNTY OF LONDON.

RECONSTRUCTION OF POOL BRIDGE, LEWISHAM.

The London County Council invites

Tenders for the Reconstruc-

TION of the COUNTY BRIDGE known as Pool Bridge carrying Southend Lane over the Pool River in the Metropolitan Borough of Lewisham.

Persons desiring to Tender may obtain the Form of Tender, etc., on application to the Chief Engineer at The Old County Hall, Spring Gardens, S.W. 1, upon payment of the sum of £3. This amount will be returnable only if the tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract documents may be inspected before the payment of the fee.

No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.E. 1, after Four p.m. on Monday, 28th May, 1923, will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 445

COUNTY OF LONDON.

WIDENING OF YORK ROAD BRIDGE, KING'S CROSS.

The London County Council invites

Tenders for the Widening of

YORK ROAD BRIDGE, King's Cross, over the Regent's Canal, in the Metropolitan Boroughs of St. Pancras and Islington.

Persons desiring to Tender may obtain the Form of Tender, etc., on application to the Chief Engineer at The Old County Hall, Spring Gardens, S.W. 1, upon payment of the sum of £3. This amount will be returnable only if the tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract documents may be inspected before the payment of the fee.

No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.E.1, after Four p.m. on Monday, 28th May, 1923, will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 446

ADMINISTRATIVE COUNTY OF LONDON.

The London County Council invites

Tenders for Water-softening

and DE-OILING PLANT for the Northern Outfall Works, East Ham, E. 6 (alongside Beckton Gasworks); each plant to be capable of dealing with 1500 gallons of water an hour.

Persons desiring to Tender may obtain on and after Monday, 14th May, 1923, the Drawing, Specification, Form of Tender, etc., on application to the Chief Engineer at the Old County Hall, Spring Gardens, S.W. 1, upon payment of the sum of £2. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application and the drawing, specification, and other contract documents may be inspected at the Old County Hall before payment of the fee.

No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.E. 1, after Four p.m. on Monday, 28th May, 1923, will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 433

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,
are prepared to receive

Tenders for the Supply of :—

1. PLATE GLASS,
2. LAMPS AND FITTINGS, LAMP GLASSES, etc.

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W.1.

Tenders, addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked :—"Tender for Plate Glass," or as the case may be, must be left with the undersigned not later than Twelve Noon on Friday, the 25th May, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 5s. for a copy of each Specification.

Copies of the Drawings may be obtained at the Offices of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W.1.

A. MUIRHEAD,
Managing Director.

91, Petty France, S.W.1.,
7th May, 1923. A 473

LIVERPOOL CORPORATION WATERWORKS.

TRUNK MAIN FROM PRESCOT TO LIVERPOOL—CONTRACTS NOS. 4 and 5. RAILWAY CROSSINGS.

The Water Committee of the Liverpool Corporation are prepared to receive

Tenders from Competent

PERSONS willing to enter into a Contract for work in connection with the CROSSING of the following RAILWAYS at BROADGREEN, LIVERPOOL, viz :—

CONTRACT No. 4: CROSSINGS OF THE CHESHIRE LINES RAILWAY: ERECTION of BRICK PIERS and a 40 ins. STEEL TUBE.
CONTRACT No. 5: CROSSING OF THE LONDON, MIDLAND & SCOTTISH RAILWAY; ERECTION of a STEEL PLATE GIRDER BRIDGE and a 40 ins. STEEL TUBE.

The Plans may be inspected and copies of the Specification and Form of Tender obtained on and after Monday, 14th May, 1923, at the Water Engineer's Office, Alexandra Buildings, 55, Dale Street, Liverpool, upon payment of the sum of Three Guineas, which amount will be refunded upon receipt of a *bona fide* Tender and the return of the documents issued.

Tenders, endorsed "Tender for Railway Crossings," are to be sent through the post in a sealed envelope, addressed :—"Chairman of the Water Committee, Town Clerk's Office, Municipal Buildings, Liverpool," so as to be delivered not later than Twelve o clock noon, on Tuesday, the 29th May, 1923.

The Water Committee do not bind themselves to accept the lowest or any other Tender.

WALTER MOON,
Town Clerk.

Municipal Buildings,
Liverpool.
8th May, 1923. A 454

DEPARTMENT OF PUBLIC WORKS,
Sydney, 31st January, 1923.
SYDNEY HARBOUR BRIDGE TENDERS—EXTENSION OF TIME.

Tenders are Invited by

the Government of New South Wales for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF A CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1600 feet in the clear, centre to centre of main piers, and a length of main bridge 2600 feet centre to centre of anchor piers. The total length of main bridge and approach spans included in tender is 3810 feet; also an ALTERNATIVE TENDER for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF AN ARCH BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear centre to centre of bearings. The total length of main bridge and approach spans included in tender is 3770 feet. Either bridge is to provide for four lines of railway, six lines of vehicular traffic, and footway accommodation.

Copies of Specification, including Plans, Technical Information, General Conditions, and Tender Forms, may be obtained by *bona fide* tenderers on application to the Under Secretary for Public Works, Sydney, or to the Agent-General for New South Wales, Australia House, The Strand, London; the Minister of Railways and Canals, Ottawa; The Australian Trade Commissioner in the United States, New York; or the Bureau of Foreign and Domestic Commerce, Washington, D.C., United States.

Tenders, the time for which has been extended, must reach the Under Secretary for Public Works Sydney, New South Wales, not later than 30th November, 1923.

R. T. BALL, A 59
Minister for Public Works and Railways.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for the Opening Out,

REPAIRING and CLOSING UP of the ENGINES, BOILER and Auxiliary Machinery of the RIVER AMBULANCE STEAMER "WHITE CROSS" in accordance with specification prepared by Mr. THOMAS COOPER, M.I.C.E., M.I.M.E., Engineer-in-Chief to the Board.

Specification, conditions of Contract and Form of Tender may be obtained at the Office of the Board, Victoria Embankment, London, E.C. 4.

Tenders, addressed as noted on the form, must be delivered at the Office of the Board not later than Ten a.m. on Wednesday, 23rd May, 1923.

G. A. POWELL, A 490
Clerk to the Board.

METROPOLITAN BOROUGH OF ISLINGTON.

ELECTRICITY DEPARTMENT.

Tenders are Invited for the

MANUFACTURE, SUPPLY, DELIVERY, and ERECTION of the following:
WATER RAISING PLANT from Artesian Wells by Compressed Air Lift.
WATER TREATING PLANT.
HIGH AND LOW TENSION SWITCHGEAR for substation.

Tender forms, specification, etc., are obtainable by application in writing on or after May 10th to the Chief Electrical Engineer, 60, Eden Grove, Holloway, N. 7. Tenders, which must be on the prescribed form, with covering envelope endorsed, are to be received by me not later than NOON on WEDNESDAY, 30th May, 1923.

By Order,
C. G. H. FLETCHER,
Town Clerk.

Town Hall, Upper Street. N. 1,
4th May, 1923. A 483

APPOINTMENTS OPEN.

UNIVERSITY OF BIRMINGHAM.

JAMES WATT RESEARCH FELLOWSHIP.

The Council invites

Applications for the James

WATT RESEARCH FELLOWSHIP in the Thermo-Dynamics of Internal Combustion Engines. Candidates should hold an Honours Degree in Engineering of a British University, and have had some experience in Research. The Fellowship has at present an annual value of £220, and is renewable. Applications should be sent in not later than 31st of May, 1923.

Further particulars may be obtained from the Dean of the Faculty of Science, The University, Edgbaston Birmingham.

GEO. H. MORLEY,
Secretary.
A 464

WEST RIDING OF YORKSHIRE RIVERS BOARD.

Applications are Invited for

the POST of CHIEF CHEMIST on the staff of the Chief Inspector of the West Riding of Yorkshire Rivers Board, at an inclusive salary of £600, rising by annual increments of £25 to a maximum of £700. Some knowledge of Engineering will be an advantage. Full particulars on application.

H. F. ATTEN,
Clerk and Solicitor.

71, Northgate,
Wakefield. A 448

Managing Director for Large

Shipbuilding, Engineering and Repairing Yard; good position for experienced man; financial interest not required.—Address, stating experience, A 478, Offices of ENGINEERING.

Wanted, Superintendent for

Electrical Engineering Factory. Applications are invited only from men with actual experience in controlling all departments of a Works manufacturing standard machines in quantities on repetition work. Must be disciplinarian and used to working to a manufacturing programme against delivery dates. State age, experience and salary.—Address, A 455, Offices of ENGINEERING.

Electrician Required for

tropical service; must be experienced in repairing Magnetos and Generators, also installations of lighting and power plants, and maintenance. Write stating education, qualifications and references.—BOX H 493, LEE & NIGHTINGALE, Advt. Offices, Liverpool. A 438

Wanted, Engineer with

drawing office and outside experience for Chemical Works in Scotland.—Address, A 444, Offices of ENGINEERING.

COUNTY BOROUGH OF NEWPORT.

BOROUGH AND WATERWORKS ENGINEER'S DEPARTMENT.

The Corporation invite

Applications for the Position

of :—

(1) SENIOR ENGINEERING ASSISTANT for Town Planning, at a salary of £393 2s. 6d. rising to £416 5s. 0d.
(2) GENERAL ENGINEERING ASSISTANT, at a salary of £351 10 0 rising to £370.

The increases are payable upon satisfactory service being rendered.

Candidates for both appointments should have had a varied experience of Engineering works and have passed the qualifying Examination for Associate Membership of the Institution of Civil Engineers. Consideration will be given to any certificates candidates may hold indicating special knowledge of the particular work for which they are to be engaged.

Applications endorsed "Town Planning Assistant" or "General Engineering Assistant," as the case may be, stating age, experience, and qualifications, together with copies of not more than three recent testimonials to be delivered at my office before noon on Monday, 21st May, 1923.

W. LIONEL JENKINS,
Borough and Waterworks Engineer.

Town Hall,
Newport, Mon.
8th May, 1923. A 457

Experienced Mechanical E

GINEER REQUIRED for tropical servi... must be fully qualified and good organizer. To ta... charge of repair shops and maintenance large fl... of lorries. Age limit 36. Salary first year £... Free passages and quarters. Write stating educati... training, qualifications and references.—BOX J ... LEE & NIGHTINGALE, Advt. Offices, Liverpool. A ...

Structural Engineers (Three

REQUIRED for the East. Must be experienc... in erecting all classes of Brick and Steel Buildi... and Structures, and in installing all kinds of pla... light and heavy. Age 28-35, single, Three yea... Agreement. ...
Salary £425 upwards, free quarters but witho... messing, and free passage out and home.
Write, giving full particulars to BOX H, c/o T... REGENT ADVERTISING SERVICE LTD., 4, London W... Buildings, E.C. 2. A ...

A Thoroughly Competen

Civil ENGINEERING ASSISTANT R... QUIRED in London Office, with considera... experience in the design of Steel and Reinforc... Concrete Bridges and other structures.—Ap... stating age, experience and salary required ... STEWART & McDONNELL, 6/7, Cowley Stre... S.W. 1. A ...

SINGAPORE IMPROVEMENT TRUST, SINGAPORE, STRAITS SETTLEMENTS.

SECOND TECHNICAL ASSISTANT.

Required, for Service wit

the Trust, a SECOND TECHNICAL ASSIS... ANT, age 25-30, unmarried, on a three years' Agr... ment, with possible extension. He must have h... a good general education and technical training a... Civil Engineer. Preference will be given to can... dates who have passed the examination and ho... the diploma of the Institution of Civil Engineer... or of the Institution of Municipal and Coun... Engineers, or of the Town Planning Institute. ... will be an advantage if candidates possess perso... experience as Assistant Engineers in the worki... of the British Housing and Town Planning Ac... (1875, 1890, 1900 and 1919), viz.:—The Improvem... of Congested Dwelling Areas, Re-Housing, Gene... Housing Schemes, Land Development for Housi... Re-Planning and Land Re-Distribution Scheme... Suburban Planning, including the usual work ... surveys, roads, lay-outs, and general town planni...
The salary will be 6000 dollars for the fir... 6480 dollars for the second, and 6960 dollars ... the third year, paid monthly in dollars (... currency of the Colony), the value of the doll... being two shillings and fourpence sterling. T... pay of the appointment for the first year ... this rate would be £700. A local transpo... allowance, subject to variation from time ... time as may be sanctioned by the Trust, w... be paid. Free first-class passage will be provide... with half pay during the voyage out. T... selected candidate must pass a medical examinati...
Applications, stating whether married or sing... age, and giving concise dated details of educati... training and experience in general (including W... Service) if any, with full details of experience in t... above class of work, must be accompanied by copies ... testimonials and personal references, and ... lodged with Messrs. C. C. LINDSAY & PHIRC... M.M.Inst.C.E., 180, Hope Street, Glasgow, Agen... to the Trust, not later than Tuesday, 15th M... 1923. A ...

Draughtsmen Required fo

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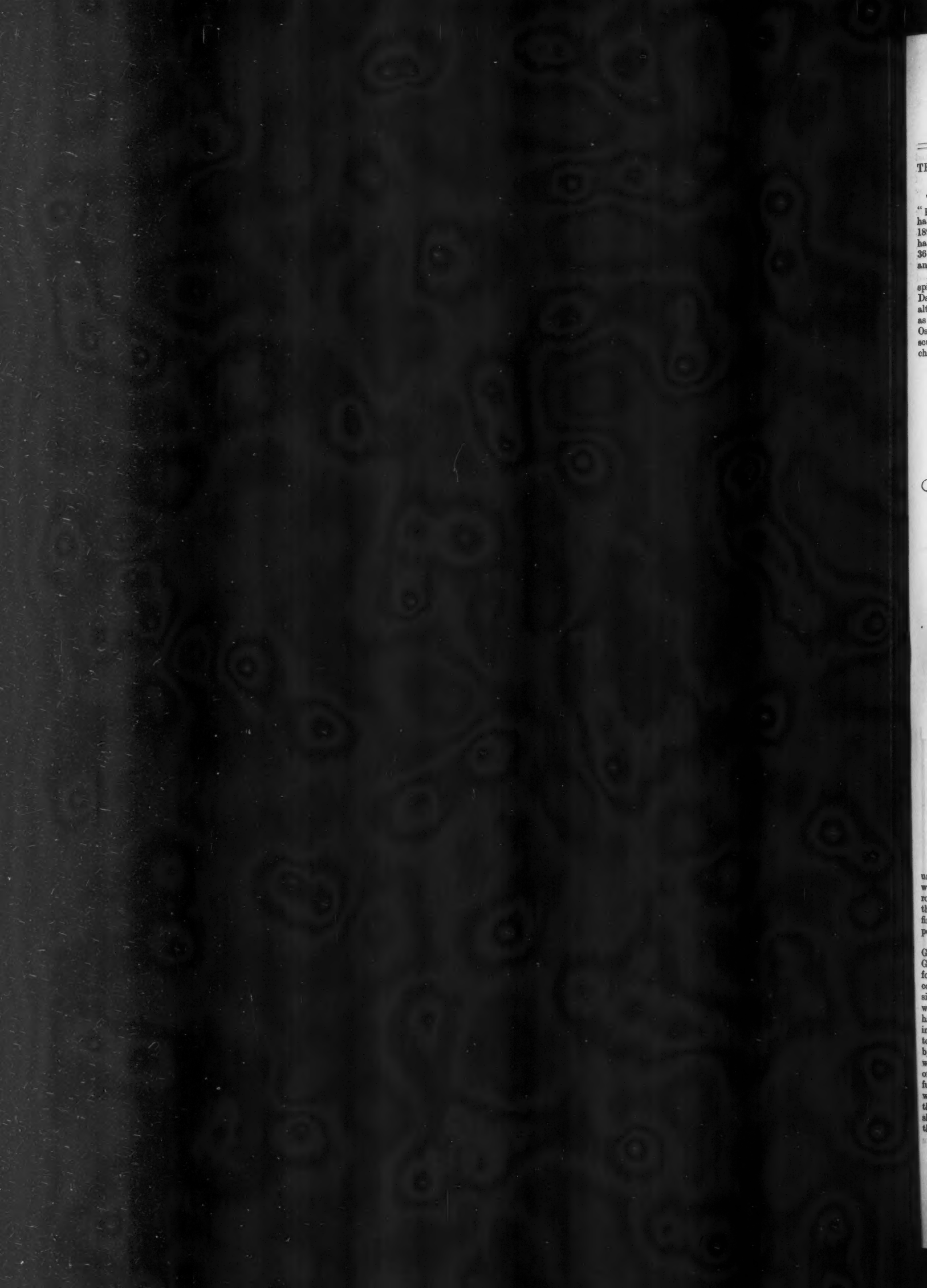


THE MOVING OF THE "VINDICTIVE."

By DUDLEY E. J. OFFORD, R.C.N.C.

THE Vindictive was a second-class cruiser of the "protected" type, built in H.M. Dockyard, Chatham, and completed towards the close of the year 1898. She was 320 ft. long between perpendiculars, had a beam of 57 ft. and a depth amidships of 36 ft. The designed draught was 20 ft. forward and 22 ft. aft, giving a displacement of 5,750 tons.

It will be recalled that after taking a very conspicuous part in the raid on Zeebrugge on St. George's Day of 1918, the vessel returned to Dover, and although very much damaged was quickly prepared as a blockship, and was sunk at the mouth of Ostend Harbour on May 10 of the same year. The scuttling was affected by means of large explosive charges placed in the double bottoms of the ship under the main divisional bulkheads. These charges were placed in all three boiler rooms, both engine rooms, and in the magazines forward and aft of these compartments, and were arranged to be fired simultaneously from a convenient upper deck position.

From the state of the wreck at the time of the German evacuation it would appear that the Germans had no intention of salving the vessel, for they had stripped her of all accessible brass and copper. Every deck plate on the main deck, all side scuttles, gun ports, bearings, brasses, clips for watertight doors, electric cable and fittings, &c., had been taken away. This in itself greatly impeded the salvage work, for the port holes all had to be blanked off and all the holes left in the decks by the removal of the deck plates had to be dealt with. The Germans had also stripped the vessel of all superstructure above the upper deck, that is funnels, bridges, deck-houses, &c., and the bulwarks were in course of removal when the Allies re-entered the port. In connection with this stripping of the ship there is one rather interesting fact, namely, that the conning tower had been lifted from its original position, turned through 180 deg., and fastened down on the upper deck, thus making an excellent armoured position looking out to seaward.

The position of the vessel in the harbour when the preliminary survey was made soon after the Allied re-occupation, was as shown on Fig. 1, the wreck having a list of about 1 deg. to port. The entrance to Ostend is formed by two timbered piers facing out practically N.W., and the vessel was lying almost at the head of the easternmost of these two piers, with her bow pointing into the harbour and about 21 ft. from the pier, whilst her stern was more towards the centre of the channel, being about 120 ft. from the pier. In this connection it may be of interest to state that her helm was subsequently found to be "hard a starboard."

The vessel lay in a very exposed position, and even during summer months it was not unusual for the swell to be so heavy as to prevent any vessel from getting alongside the wreck for several days at a time, whilst during the winter season it was the exception for craft to lie alongside except at dead low water. This, of course, greatly impeded the general work of salvage.

A very severe gale was experienced during May, 1919, and it was afterwards found that the vessel had broken her back. The fracture occurred between the aftermost of the three boiler rooms and the engine rooms. The ship's side was fractured from the upper deck down to about 8 ft. above the turn of bilge, and below this the bottom plating was buckled. The upper and main decks were torn open right across the vessel, the opening of the upper deck being about 16 in. The thick protective deck was also torn open at the line of butts. This deck, as is usual in H.M. Service, was not worked as a strength deck, but only as protection from gun-fire and, in consequence, the two thicknesses are worked to form butt straps to each other. In the vicinity of the fracture this deck, although of practically its maximum thickness, had no appreciable longitudinal strength, and it was opened as a result of the fracture to an average distance of about 6 in. As a result of the fracture the after end of the ship dropped about 7 ft. from its original line, *i.e.*, 7 ft. in a length of 140 ft. Fig. 3 shows the exterior aspect of the fracture.

Towards the end of June, 1919, orders were received from the Admiralty to proceed with the salvage operations on Vindictive. Previous to this date only a causal survey had been made. Immediately on receipt of these orders a more extensive survey was carried out, and it was ascertained that the explosive charges had been so effective that for a length of about 180 ft. amidships it was quite impracticable to repair the damage to the outer bottom of the wreck. Not only was the ship's bottom so badly blown as to allow the water level in the boiler rooms, &c., to be sensible to the least swell running outside the ship, but the explosions had left so much *debris* in the already crowded machinery spaces as to render access by divers only possible with the gravest risks. At the ends of the wreck, however, things were more hopeful, and the pumping tests indicated that a good deal of buoyancy could be recovered in these parts. After this survey the scheme of salvage was very carefully gone into, and many suggestions and schemes were given most detailed consideration. It was finally decided to lift the wreck *in toto*: the two portions to be braced together with additional structure sufficiently strong to withstand the lifting stresses.

Fig. 1.

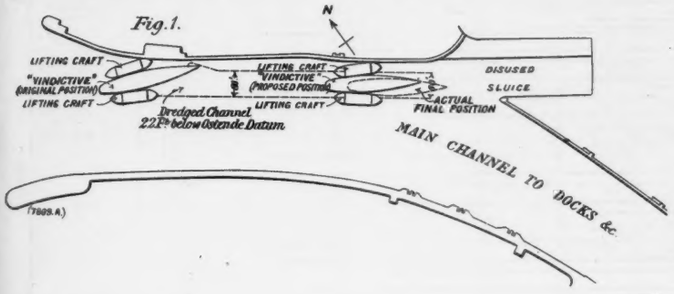
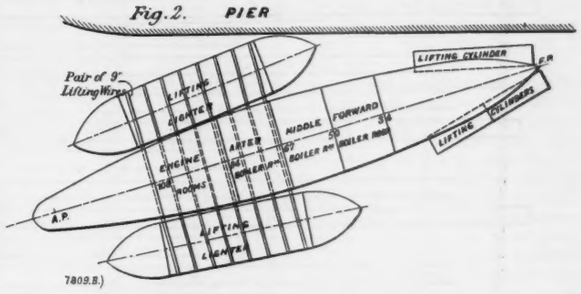


Fig. 2. PIER



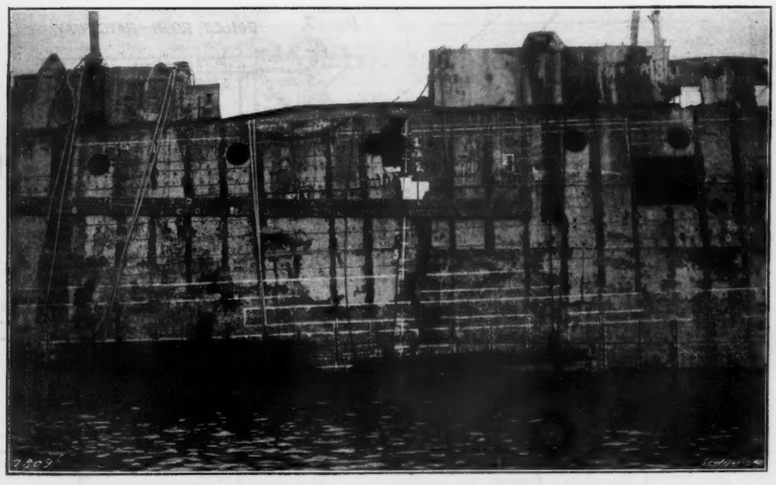


FIG. 3.

Due to the proximity of the eastern pier it was only possible to use two of the large lifting craft, one at each side of the wreck at the after end, but it was desired to place them as far forward as the pier would allow. The special lifting cylinders which had been built at Portsmouth Yard for the raising of the sister ship Gladiator were still available, and it was decided to use these at the forward end where there was just sufficient space between the ship and the pier to allow of their being placed in position. Fig. 2 shows the position of the wreck relative to the pier and also the positions selected for the lifting craft and lifting cylinders.

These craft were, of course, not nearly sufficient to carry the total weight of the wreck, and it was therefore necessary to recover a considerable amount of buoyancy from the ship herself. The protective deck just dried at low water and it was decided to render this deck watertight for the full length of the vessel and to make good all the side plating above this level. In addition, certain compartments at the ends of the vessel and below this deck could be recovered. To augment the buoyancy thus obtained it was proposed to use compressed air on the compartments below the protective deck throughout the central portion of the wreck where the bottom was so badly blown as to preclude all hope of direct recovery.

For purposes of moving the vessel when afloat the draught which had most to be considered was the maximum draught. Due to the fracture and the consequent drop of the stern this would occur at either the forward or the after cut up. The ideal floating trim was therefore that which gave the same draughts at these two points. This was the condition sought after.

Detailed calculations were made of the magnitude and distribution of weight to be lifted and of the buoyancy which might reasonably be expected to be recovered, so that the position of the lifting barges and cylinders could be arranged to result in the vessel eventually floating on an even keel. It was

estimated that this could be arranged, and that the final draught would be 30 ft. at both the forward and after cut-up. Calculations were also made of the forces which would operate across the fracture when the vessel was afloat and at intermediate conditions during the rise of tide. The maximum bending moment was found to occur when the tide was at 8 ft. above the Ostend datum and was a sagging moment of 68,000 ft.-tons. As the tide rose the magnitude of the bending moment fell until when the vessel was fully afloat it was of the order of 23,000 ft.-tons. Calculations were also made regarding such matters as stability, transverse strength and strength to withstand various local stresses, so that all necessary precautions could be taken for safety.

It is now proposed briefly to outline the various items of work carried out and the methods employed in connection with the actual task of salvage. The work may be conveniently divided under the following sub-heads :—

(1) Bracing structure across the fracture.
(2) Making watertight and airtight the protective deck.
(3) Reclaiming end compartments.
(4) Removal of mud.
(5) Placing lifting wires.
(6) Dredging a channel along which to move the wreck.

Bracing Structure across the Fracture.—The stresses that were likely to arise had been calculated and were as already stated. These it will be noted were sagging stresses, but it was also necessary to provide for stresses which would arise on account of bad weather, whilst the vessel was being prepared for lifting. These conditions would cause hogging stresses and therefore both sets of forces had to be provided for. Bracing by means of reinforced concrete was carefully considered, but finally it was decided that steel bracing was more practicable and more reliable under the conditions existing. A scheme of steel bracing was therefore evolved which it was estimated would in conjunction with the ship's structure be just strong enough, with a small margin for safety, to withstand the calculated lifting stresses. This scheme was as shown in Figs. 4 to 6. It will be noticed that strong upper deck through beams, well supported by pillars and deep web frames carried down to the protective deck were worked across the ship, one on each side of the fracture. On the upper deck itself six box girders were worked—each 54 ft. long and 4 ft. by 2 ft. in section. Down each side of the ship 12-in. channel bars, 40 ft. long were worked and staggered so as to distribute their stresses over as large a number of the ship's frames as possible. The original scheme provided for six in No. 12-in. I-bars to be worked along the slopes of the protective decks, but this was afterwards found to be a very long operation on account of the short time during which the deck was dry, and also on account of the thickness of the deck necessitating the use of tap rivets. These strength members were therefore sacrificed and longitudinal bulkheads were substituted in their stead. These bulkheads were worked between the main and the protective decks, and were continuations of the divisional bulkheads to the upper bunkers, which in the original ship stopped at the transverse bulkhead about which the fracture occurred. Although it was at first proposed to build in four of these bulkheads, eventually only three were built, *i.e.*, two on the port side and one on the starboard side. The two bottom ship-side channels both port and starboard were also omitted. The completion of this work was delayed by unfavourable weather, but a later report from the divers as to the state of the ship's bottom under the fracture was more favourable than had been allowed for in the initial calculations, and due to the additional strength accruing from this source it was decided that under the circumstances the omission of these last strength members was a justifiable risk.

The stresses in the upper deck girders would in the ordinary course have been entirely transmitted to the upper deck beams to which they were attached. These beams were therefore supported by a system of diagonal wood shoring, whereby a proportion of the stress was distributed to the main deck beams.

Making Watertight and Airtight the Protective Deck.—This was naturally one of the longest operations in connection with the salvage work. The Germans had removed all available brass and copper, and this left hundreds of small holes in this deck which had to be located and plugged. The armoured hatches had been either removed or else so stripped of metal fittings that it was necessary in every case to substitute wood patches, cement boxes and covering being fitted over the woodwork in those places where air pressure was to be employed.

The two principal items of work under this heading were, however, due to (*a*) the boiler-room uptakes and engine-room ventilation, and (*b*) the protective deck fracture. As regards (*a*) the funnel uptakes, bunker ventilation pipes, fans and all similar fittings were first burnt away and removed from the boiler room and engine room spaces above the protective deck, so that eventually over each of these compartments a large well was left (about 16 ft. by 25 ft.) extending from the upper to the protective deck level, the bottom being formed by the nests of armour bars which serve as protection from gun-fire in lieu of the protective

Fig. 4.

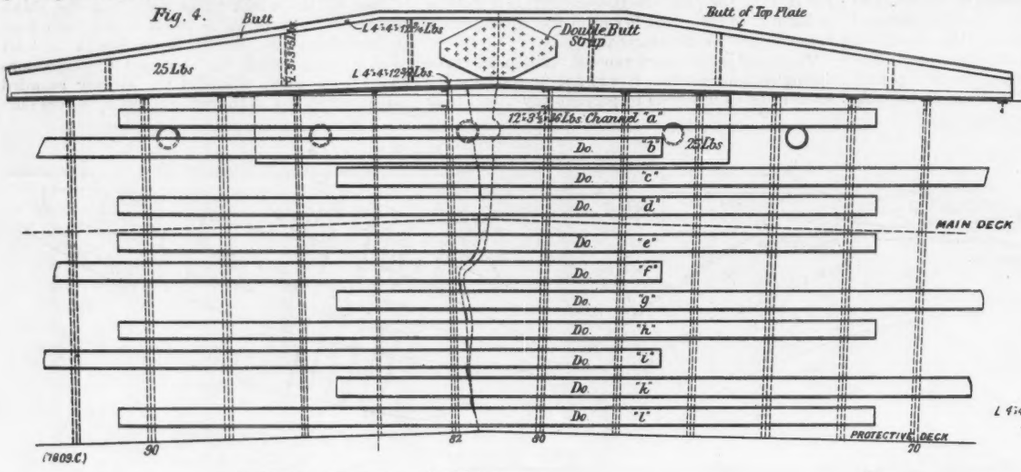


Fig. 5.

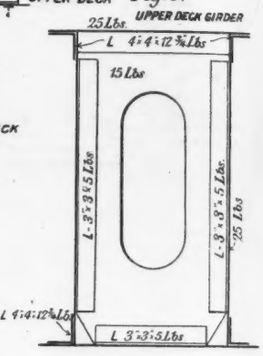


Fig. 6.

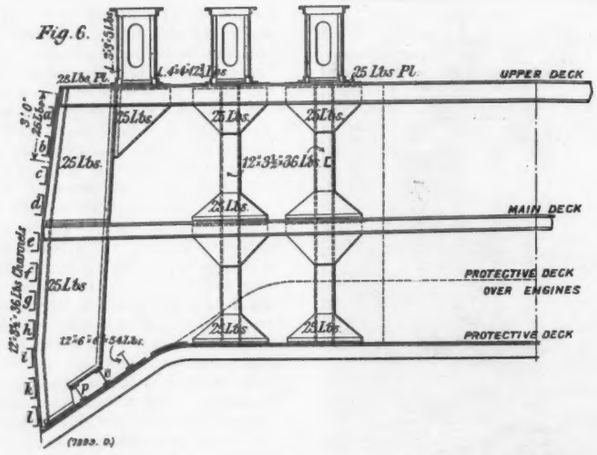


Fig. 7. BOILER ROOM HATCHWAY

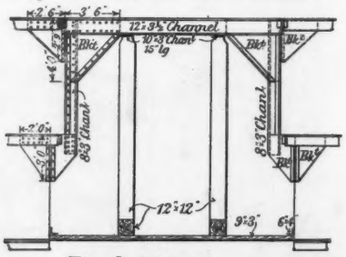


Fig. 8. PLAN

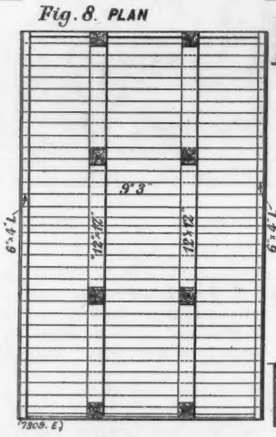
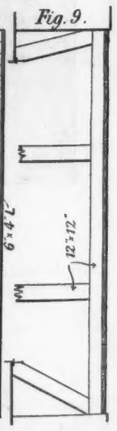


Fig. 9.



deck itself. These armour bars were next cut free and lifted out, and a wood platform of 3-in. red pine with planks worked athwartships, was laid on the foundations of the bars. This platform was then secured, shored and lightly caulked. To house the upper end of the central shores new beams were worked across the opening at the upper deck level. These beams consisted of 12-in. channel bars, well as possible. After this, two wooden bulkheads were built across the ship, one about 3 ft. forward and the other about 3 ft. aft of the line of the fracture. These bulkheads extended from the protective to the main deck. On the sloping side portions of the protective deck cement bag walls took the place of the wooden bulkheads as these were more convenient to erect on account of the shape of the deck,

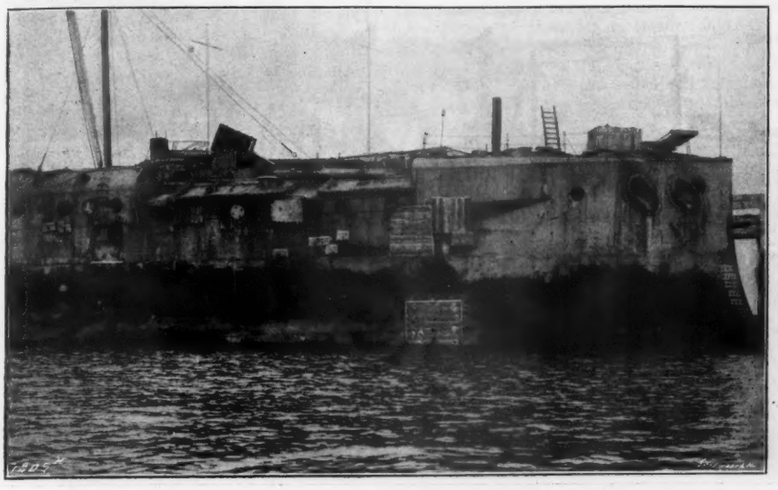


FIG. 10.

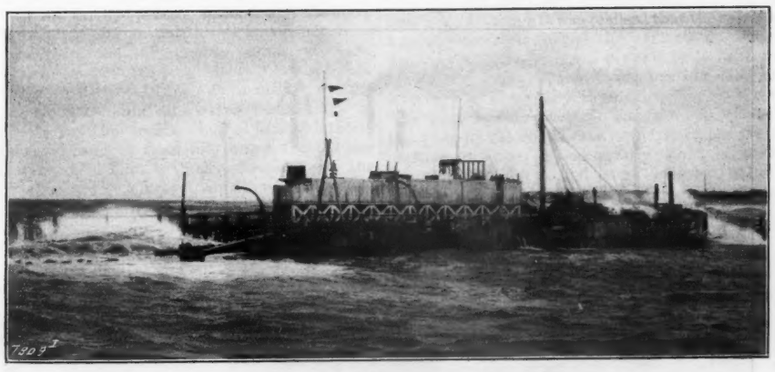


FIG. 11.

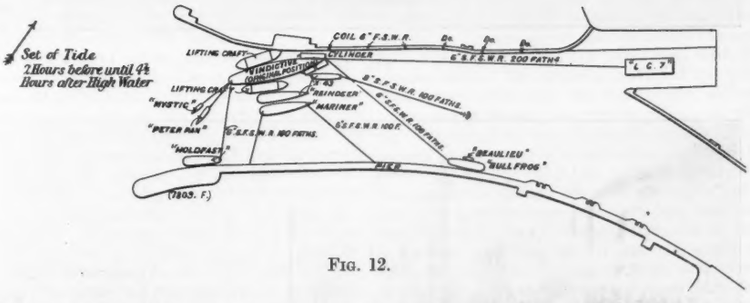


FIG. 12.

Key to Craft in Fig. 12.—"Reindeer" and "Mariner," Salvage Steamers supplying Electrical Power, Compressed Air, &c. "L.C. 7," Lifting Craft, grounded and fitted with Capstans. "Holdfast" and "Bullfrog," Moored to Pier and fitted with Capstans. "X. 43," Air Supply to Lifting Cylinders. "Mystic" and "Peter Pan," Tugs.

supported at the ends with bracket and diagonal plates. The wooden platforms were then covered with cement to a depth of about 24 in. Figs. 7 to 9 show the details of the covering to one of the boiler rooms, the arrangement for the engine rooms being similar in principal, but the scantlings, &c., were modified to suit the difference in area of the surface dealt with.

As regards (*b*) the fracture was first wedged and covered with wood to render it as nearly watertight and also due to this portion of the deck never drying even at dead low water springs. The space between these two bulkheads was then filled solid with cement up to the level of the main deck.

Reclaiming End Compartments.—In connection with this item of work it may be well to refer briefly to the plan of campaign which was decided upon for the general conduct of operations. One of the first things done was to build a substantial wooden gangway from the eastern pier to the forecastle of the wreck so that workmen, stores, plant, &c., could be got on board when the weather was too rough for boats to come alongside the vessel.

After this the portion of the ship back to the break of the forecastle and between the main and forecastle decks, was made watertight and fitted with proper watertight hatches for access, &c., The space thus recovered was then used as a store, workshop, machinery compartment, &c. In it were placed two vertical boilers, a steam air compressor, a portable motor alternator for driving two 4-in. submersible pumps, and a small petrol-driven lighting set.

At frequent intervals and for many days at a time no vessel could approach the wreck, but once this plant was on board and fitted up a large amount of the work at the fore end could be proceeded with almost irrespective of the weather conditions. The work of reclaiming the compartments at the fore end of the ship was then proceeded with. Some idea of the work involved in making the ship's side watertight may be gleaned from Fig. 10, which shows the large number of shell holes, &c., which existed and had to be patched.

Amongst the many little hindrances which made progress at times very slow were such items as accumulations of poisonous gases, which necessitated the men working in gas helmets. Mud and sand had also accumulated in nearly all compartments until in many cases they were filled to the top of the hatch coamings. All this had to be removed before the work of patching, &c., could be undertaken. Buoyancy drums had been placed in the vessel prior to the Zeebrugge raid and had not been removed before she was brought to Ostend. By this time these were naturally no longer watertight, but were just so much lumber in the ship and had all to be removed. They had been very well packed into the various compartments and when it was necessary to remove them, especially as this work had in nearly all cases to be done by the divers, the task proved to be a very long and tedious one. At the after end the recovery of compartments was further complicated by the short time that work could be carried out before the rising tide necessitated the abandonment of this end of the ship. Eventually 82 separate watertight compartments were recovered, giving a total buoyancy of over 3,500 tons. Fig. 11 shows the wreck during the preliminary operations.

Removal of Mud.—The extraordinary extent of the silt in the region of Ostend is well known, but the extent to which the wreck had become silted up is perhaps somewhat surprising. The mud level throughout the entire ship was on an average only about 6 ft. below the crown of the protective deck. The silt, moreover, was not mud, but very fine-grain sand. On account of the explosions the machinery compartments, &c., were full of *debris*, and this, of course, was all embedded in the sand which made its removal all the more difficult. To remove the sand from the large compartments two 12-in. steam pumps were used, one being arranged to draw water from the sea with its discharge down into one end of the space in hand. This discharge stirred up the sand and the other 12-in. pump was used in the ordinary way and discharged it overboard. As soon as a compartment was freed of sand it was necessary to close it up completely, otherwise in a matter of two or three weeks it would contain a layer of fresh sand a foot or more deep.

Placing the Lifting Wires.—The positions of the lifting lighters and cylinders has already been referred to and illustrated in Fig. 2. This plan also shows the position of the lifting wires. The wires were in all cases 9 in. in circumference and of the usual special flexible quality. Sixteen wires were required for the lifting lighters and nine for the lifting cylinders. To place these wires in position a series of tunnels were bored under the wreck, and small messenger wires passed under by divers. These messengers were then used to pull under the actual lifting wires. The tunnels were bored by means of powerful hydraulic monitors worked by special craft fitted with large capacity high-pressure pumps. The monitors cut into the sand, mud, &c., which was then removed by means of air ejectors. The work of tunnelling for the wires to the lighters was greatly hampered on account of the large amount of old timber, &c., which had to be removed

THE MOVING OF THE "VINDICTIVE."

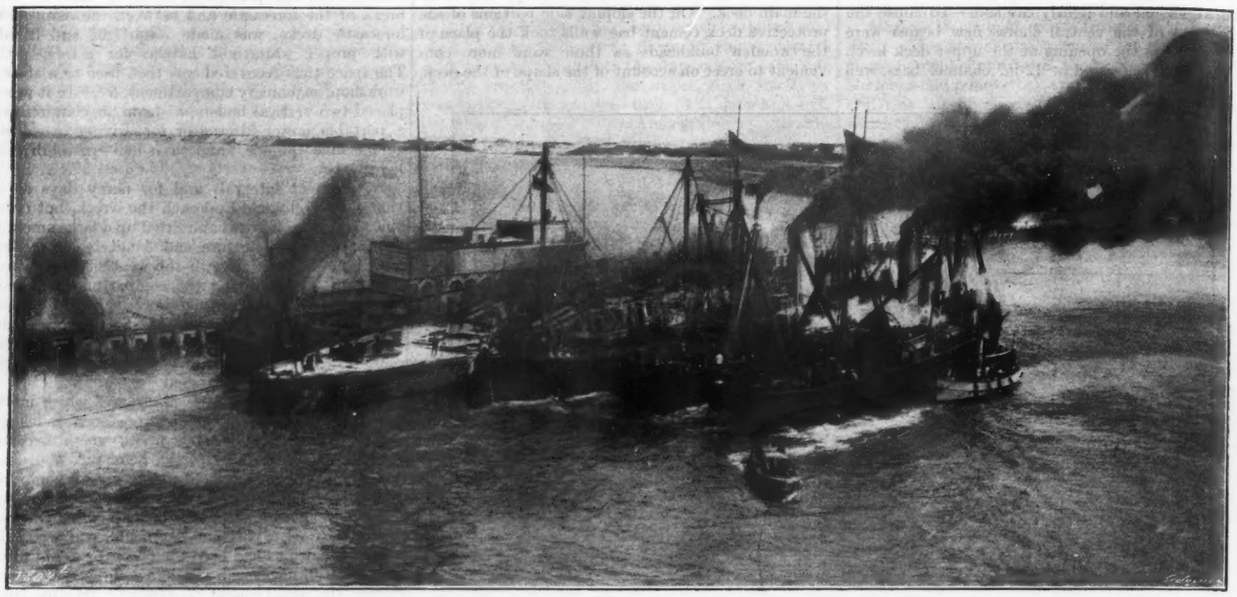


FIG. 13.

as the tunnels progressed, this timber being no doubt the wreckage or remains of some old pier which had existed previous to the present one. At the forward end when tunnelling for the wires to the lifting cylinders it was found that the bow of the wreck was sitting on the masonry foundations of the existing pier. This, together with the somewhat abnormal spell of bad weather which occurred just prior to the lifting date greatly delayed the operation of placing these wires. Fortunately, preliminary air pressure tests had shown such good results that it was decided that the large lifting cylinder could be dispensed with without exceeding the draught that had been legislated for. The two small cylinders were therefore employed one on each side of the bow, and for their use only four wires were required, and these could all be passed through a single tunnel.

Dredging.—Assuming the wreck afloat the next most important question was—To where shall she be moved? Many considerations were involved in this issue, but obviously it was a question primarily for the local harbour authorities and for the Belgian Government to decide. A conference was therefore convened, and after all the aspects of the question had been thoroughly discussed it was decided to move the wreck ahead up into the harbour towards the disused sluice at the base of the eastern pier. The position decided upon was that indicated on Fig. 1. As the calculations showed that the vessel would be drawing about 30 ft. of water when afloat it was necessary to dredge a channel along which to move the wreck, the average depth ahead of her being only about 20 ft. at high water. The necessary dredging was accordingly undertaken, but presented no difficulties beyond those arising out of bad weather, but this had fortunately been anticipated by allowing a good time margin for the completion of this work.

For purposes of pumping out the vessel at the actual lifting operation it was decided to employ the standard type of electrical submersible pump, the necessary power (viz., three-phase alternating current) being supplied by the two salvage steamers, Reindeer and Mariner. The 82 compartments recovered were divided into groups for pumping purposes and the following pumps were employed: 1 in No. 8 in., 4 in No. 6 in., 15 in No. 4 in., giving a total hourly output of about 2,700 tons. In addition, wooden transverse bulkheads had been built across the ship both forward and aft of the

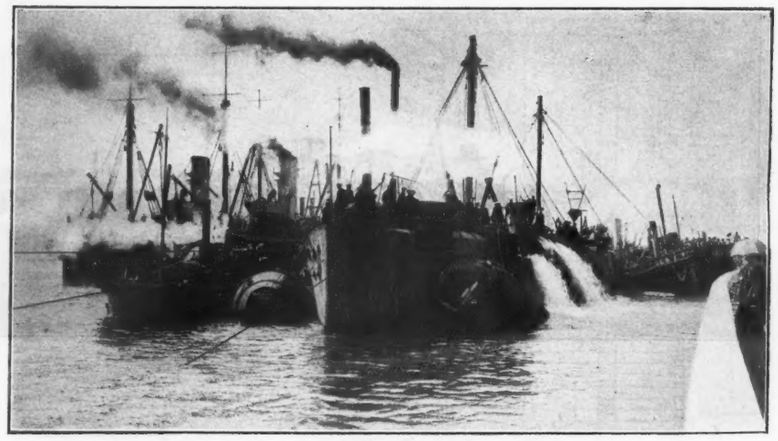


FIG. 14.

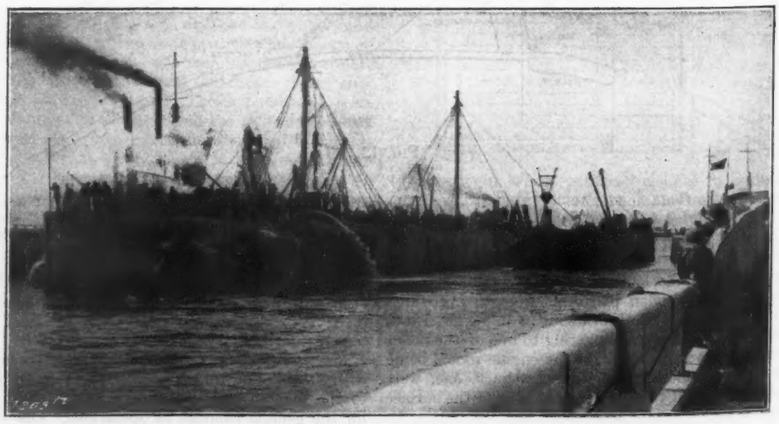


FIG. 15.

concrete block which had been worked in wake of the fracture. These bulkheads extended from the protective to the upper decks and were intended to confine the water should a break through occur at the fracture. To deal with the influx of water in any such emergency two 12 in. steam pumps were placed with their suctions between these two bulkheads. Another 12-in. steam pump was fitted up so as to be able to rapidly pump water into either the port or starboard upper bunkers should this be necessary to correct any excessive heel of the ship when afloat.

Compressed air was supplied to all the boiler rooms, both engine rooms and to the submerged torpedo room, each of these compartments being fitted with a 3-in. supply pipe, the supply being derived from six large steam-driven air compressors, two being on the wreck itself and the other four on the salvage vessels. In addition the three boiler rooms had auxiliary supplies through 1-in. pipes, from three portable motor-driven air compressors. The air pressures obtained in each compartment were indicated by large dial low-reading pressure gauges, all mounted on a board in a conspicuous position.

It had been decided at the close of the conference referred to above that if weather permitted the attempt to lift would be made on Sunday, August 15, 1920. Although during the previous weeks the weather was unusually boisterous on the Friday before the date fixed, *i.e.*, on August 13, the wind had dropped, the swell was rapidly diminishing and there was every indication of a spell of fine weather. The organisation of the various salvage craft for the lift was as shown on Fig. 12, and on Saturday, August 14, the lifting cylinders and lighters were placed in position and the wires arranged for pinning at low water on the 15th. Towards midnight on the 14th the salvage vessels Mariner and Reindeer took up their positions and the various connections were made for the submersible pumps, air compressors, steam pumps, &c. About 2 hours before low water on August 15, *i.e.*, at about 6 a.m., the pumps were started and all recovered compartments pumped out. The tanks of the lifting lighters were flooded, and at dead low water the lighters were "pinned." That is to say the clamps to the lifting wires were tightened up after as much as possible of the slack in the wire had been taken in. The lifting cylinders were also flooded and their lifting wires hove taut and pinned. As the tide rose the lifting lighters were pumped out and also the lifting cylinders, and at 9 a.m. the compressed air was turned on to all connections.

Soon after 11 a.m., the stern of the wreck began to lift and continued to do so until by about 1 p.m. the wreck was completely afloat and drawing about 30 ft. 6 in. forward, and 28 ft. 6 in. aft. On this day, however, the lifting cylinders were not effective on account of the large amount of slack in the pinning wires which permitted the cylinders to float freely before any strain came upon them.

The vessel was, of course, only a foot or so clear of the bed in which she had been resting, and this bed was naturally banked up several feet on either side of her. On the Sunday therefore it was not possible to completely free the vessel from this self-made dock before the tide had fallen sufficiently to cause her to ground again. However, the weather prospect was still good, and so it was decided to make a second attempt on the following day. It was thought advisable to keep the vessel pumped out, and the lifting lighters pinned so that the wreck would float again on the night tide, but precautions were taken to ensure that no movement in the harbour should occur.

During the night the wires in connection with the lifting cylinders received attention, and the following day a fairly satisfactory "pin" was obtained. The cylinders were at first completely immersed and contributing their full buoyancy, but after a short time the forward pair of wires rendered in the clamps allowing the forward ends of the cylinders to rise above the water level; however, even so the cylinders were contributing probably three-quarters of their full buoyancy.

On this day the vessel eventually floated at a draught of 29 ft. 6 in. forward and 28 ft. 6 in. aft. The vessel was fully floated by about 1.15 p.m., although high water was not until about 3 p.m. By first towing the wreck several feet astern and then swinging her bow out towards the centre of the channel, she was successfully cleared from her bed, and when the capstans on the barge L.C. 7 were started, the vessel moved ahead quite easily, and only a few minutes were occupied in moving her from her original position to the one in which it had been proposed to place her. The total movement effected was 826 ft. (see Fig. 1).

The vessel was in her new position before actual high water and by about 4 p.m., the first ship entered the now clear harbour, after being closed to traffic since noon on August 14 (*i.e.*, a total of about 52 hours only). When the vessel was fully afloat on August 16, the lifting forces operating were found to be as follows:—

	Tons.
Recovered buoyancy	3,500
Air pressure buoyancy	500
Lifting lighters	1,100
Lifting cylinders	150
	5,250

During the lifting operations the maximum breakage recorded was 3½ in. in a length of 220 ft., not an excessive amount under the circumstances of the fracture and the force distribution, and a subsequent examination of the bracing structure revealed only slight evidence of straining. Figs. 13, 14 and 15 show operations at the final stage with the wreck afloat and just about to be moved.

The vessel had previously been presented to the Belgian Government, and the responsibility of the British Admiralty ended with her removal from the mouth of the harbour to the position desired by the Belgian Authorities. She was, therefore, allowed to settle on the bottom in the position shown in Fig. 1, the lifting barges, cylinders, pumps, &c., removed and the vessel securely moored in her new position. Although it was realised that the vessel was a most interesting relic of the war and would be of great interest to visitors, her condition was such that it was impracticable to use her as a show ship and it was eventually decided to break her up. This work has now been in hand for some months, but even in the comparative shelter of her present position progress is necessarily slow, However, the primary object had been achieved, namely, her removal from the mouth of the harbour where although she did not completely block the port, her presence was a continual source of danger to navigation.

5,000-KILOWATT BRUSH-LJUNGSTRÖM STEAM TURBINE.

(*Concluded from Page* 545.)

THE emergency governors are fitted into the generator shafts, as shown in Fig. 2, on Plate XXXIV, published with our last issue. Details to a larger scale are given in Figs. 18 and 19, on Plate XXXV, which accompanies our present number. Each governor consists simply of a spring-loaded plunger mounted in a hole drilled through the turbine shaft. The centre of gravity of this plunger does not coincide with the shaft centre, and when the turbine is running, the centrifugal force developed tends to make it move and compress the spring shown. So long as the speed is below the designed limit, however, this spring holds the left-hand end of the plunger home against the seat shown, but if this speed be exceeded the end protrudes and strikes the trigger A, thus slackening the cord B, which, as shown in Figs. 20, 21, and 22, leads to a bye-pass valve on the governor relay, and causes it to open, thus releasing the oil pressure below the relay piston, when the stop valve is closed accordingly by the action of the spring. A section through this stop valve is represented in Fig. 23, where the small bye-pass valve can be seen to the right of the relay cylinder. The governor valve is, it will be seen, arranged above the stop-valve on the same spindle, and is of the balanced type, with two seats, as shown in Fig. 25. Below the stop-valve is a strainer to prevent solids accidentally entrained in the steam, being carried into the turbine blading, and below this again is a deflector which serves a similar function in respect to more massive objects. In addition this acts as an ordinary steam separator. The function of the ventilating valve shown in Fig. 25A is to admit air to the turbine on shutting down. It is opened on shutting down, and the air which passes through it is warmed by the hot piping and dries off the turbine blading, thus reducing the liability to corrosion.

The construction of the main bearings is illustrated in Figs. 26 to 30, Plate XXXV. Each rests in a bored seat in the generator framing, as shown in Fig. 2 *ante*. This seat is cut away at the bottom, so as to provide a very large discharge area for the lubricating oil when it escapes from the bearing. The shell of the bearing is, it will be seen from Figs. 28 and 30, divided into two compartments, that on the left being connected to the oil supply. To gain access to the second compartment, the oil has to pass across the upper half bearing with the two compartments, through the grooves shown, which are connected by holes, such as can be seen in Fig. 26.

Details of the Michell thrust bearings are represented in Figs. 31 and 32, Plate XXXV. The bearing will take a thrust in either direction, since pads are provided for both faces of the thrust collar. These pads are represented in section on the lower half of Fig. 31, the blocks B shown at the top of the same view being simply spacers.

The over-load valves are cut in and out automatically by the governor. As shown in Figs. 9 to 11, page 543 *ante*, they are coupled by linkage to a lever on the lay shaft, which connects together the governor valve spindle and the valve of the relay (*see* Fig. 5, Plate XXXIV *ante*). They can also be opened by the handwheel C, Fig. 33, Plate XXXV, which also shows how the two valves are coupled together. As will be seen, they are spring loaded, and this spring closes them automatically if the load falls off. The lever D is used for easing these valves periodically. This is a necessary precaution, in view of the fact that long periods may elapse between overloads.

A view of the steam gland is represented in Fig. 35, Plate XXXV. In all, the steam has to pass through 62 constrictions, the clearances in which range from 2½ mils. at the high pressure end to 5 mils. at the low. From the last constriction the steam escapes at a high velocity and, as already explained (page 343 *ante*) is caused to induce a current of air from the space E and to deliver it by an injector action through the trumpet-shaped passage shown, to the space F, which is connected up to a separate condenser, as has been already explained.

The oil cooler is represented in Figs. 36 to 42, Plate XXXV. It is constructed much on the lines of a return-flow surface condenser. The tubes are ½ in. in diameter, and No. 18 S.W.G. thick. They are expanded into gunmetal tube plates. The cooling surface provided is 100 sq. ft., and the designed flow of oil 90 gallons per minute.

The cooling water passes through the tubes, and the oil outside them. Nineteen baffles, consisting of semi-circular plates, are inserted at intervals of 3 13/16 in. in order to break up the oil flow and promote the interchange of heat with the cooling water. Three of these baffles are visible in Fig. 36, but, as will be seen from Fig. 42, consecutive baffles are set at different angles, so as to insure as uniform a distribution of the oil as possible. Each baffle plate is soldered to the tubes in three or more places. The speed of the oil past the baffles is about 1·2 ft. per second. In passing through this cooler, the oil temperature is reduced by 6° F. or 8° F., with oil entering the cooler at a temperature of 130° F.

Mention has been made of the special tackle used for lifting the turbine in and out of place. This is represented in Figs. 43 to 51, Plate XXXV. An assembling arm G (Fig. 43) is provided for each rotor, having turned on it a "register," into which the spindle of the turbine rotor fits. Having secured the spindle in position on the arm, the steam chest and the stationary labyrinth disc are next placed in position, being located by a second register. The high-pressure gland is next fixed on the shaft, and following this the rotor proper is screwed down on to the taper end of the shaft. The other rotor having been similarly assembled on a corresponding arm, it is carefully lowered to intermesh with its fellow, being guided during the operation by the centering bar J (Fig. 44). This done, the two arms are bolted together as indicated in Fig. 44. A centering ring shown at H,

Fig. 45, which is made in three segments, is now put into place, and six centering wedges shown at I, are driven in between the outer segment of the rotor disc and the stationary labyrinth disc in order to prevent fouling of the labyrinth nickels.

This done, the pair of rotors are raised into the position shown in Fig. 46, and the stirrup K attached. After which the assembling arms G can be removed and the rotors lifted into place, as indicated in Fig. 47. The two steam chest flanges (Figs. 48 and 49) are then drawn into their registers in the turbine casings, by the bolts indicated. As already mentioned, for dismantling the turbine "starting" bolts are provided by which the steam chest flanges can be cleared from their registers. These starting bolts occupy the holes marked with a cross in Fig. 49.

To force the disc off its spindle, when it is necessary to dismantle the turbine, a ring L formed in segments is placed inside the disc, where it catches under the projection provided. A screwed plug M cut with a left-hand thread, is then brought up against this ring by the box spanner, this spanner being held in place by the tap bolt O. After being loosened in this way, the "starting" tackle is removed and the disc lifted clear by the lifting bow P, Fig. 51.

The set is mounted on a Brush condenser as already explained and a Brush-Delas ejector is used as air pump. This is illustrated in Figs. 52 to 55, annexed, from which it will be seen that there are two jets in series. A special feature of the device is the water-jacketting of the diffuser tubes. It is stated that with this arrangement it is possible to place the nozzles further from the throat than is customary, and thus secure a better entrainment of the air. Should conditions vary, so that the diameter of the steam jet swells beyond the designed limit, the surplus steam is condensed by the cold wall of the convergents, and the whole discharge is then able to find its way through the throat, thus obviating the instability which often arises with air ejectors when the conditions under which they work change. The diffuser, beyond the throat, is, it will be seen, parallel in form, instead of divergent, as customary.

Owing to the water-cooling of this tube, the air is compressed nearly isothermally, thus reducing the work to be done and the volume to be delivered. The discharge from the first stage of the ejector passes into a condensing chamber as indicated in Fig. 53. Here it meets with a spray of water, which is supplied by the extraction pump. The steam condensed here is delivered into a "U" pipe communicating with the main condenser, whilst the air is drawn off by the second ejector shown on the right, by which it is compressed and delivered with the steam into the hot well, or alternatively to a surface feed heater. Owing to the water cooling of the ejectors, it is stated that the temperature of the discharge is about 212° F.

The principal components of the generators are illustrated in Figs. 56 to 59, on page 588. In Fig. 56 the stator is shown ready to receive its windings, and in Fig. 57 it is shown ready for erection. The rotor is represented in Fig. 58 with the wedges partly in place, and is shown complete in Fig. 59. These rotors are formed from solid steel forgings, which are slotted to receive the windings. They are very stiff, the critical speed being much in excess of 3,000 revolutions per minute. The ventilation is effected through axial slots in preference to radial. The air, for cooling the generator, is supplied by a separate motor-driven fan, and the whole interior is thus kept under a slight air-pressure, thus eliminating any tendency for oil or other deleterious matter to be drawn into the windings. The fan delivers air into pressure chambers which occupy a position in the main casing between the outer bearings and the alternators. From this casing the air flows axially through the openings in the stator end plates and in the stampings, and also through the air gap and through the rotor slots, thence to outlets formed by openings at the top of the periphery of the alternators. Fig. 60 on the present page gives reproductions of photographs of the turbine blading.

Independent tests were made on one of these 5,000-kw. units, installed at the Walsall Power Station, by Mr. E. M. Lacey, M.Inst.C.E., M.I.Mech.E., M.I.E.E., and Mr. H. A. Howie, M.I.Mech.E., M.I.E.E. The steam, as supplied at the stop-vale, had a pressure of 166 lb. per square inch (gauge) and a temperature of 662° F. The vacuum, corrected to a 30-in. barometer, was 28·95 and the steam consumption under an average load of 5,030 kw., was 10·36 lb. per kw.-hour. The corresponding overall efficiency ratio (stop-valve to switchboard), according to the Beama Tables, is 76·4 per cent., which is equivalent to 80·4 per cent. at the turbine coupling. It is of interest to compare the hydraulic efficiency of this turbine with that of the much larger units from which the efficiency ellipse published on page 2 of our issue of January 6, 1922, was plotted. The gland leakage may be taken as 0·8 per cent. of the total steam, and the dummy leakage as 2·5 per cent., making a total loss, extraneous to the blading, of 3·3 per cent. Adding the losses beyond the turbine couplings the steam consumption per "indicated" kw. may be taken as $10{\cdot}36 \times 0{\cdot}917 = 9{\cdot}502$ lb. per kw. hour. Following the methods described in the article of January 6, 1922, already cited, it appears that the hydraulic efficiency of the turbine was 81·3 per cent., and the effective thermodynamic head (assuming a pressure drop of 9 per cent. through the valves), was 245 Centigrade-lb. heat-units. The value of K for this turbine is 266,000, so that $\frac{U}{K} = 1{,}086$. For this value of the ratio $\frac{K}{U}$ the curve published gives 81 per cent. It is possible that the dummy leakage is a little less than above taken, which is a maximum figure, but the probable error will hardly exceed one-fifth the total, which would affect the hydraulic efficiency by not more than 0·5 per cent.

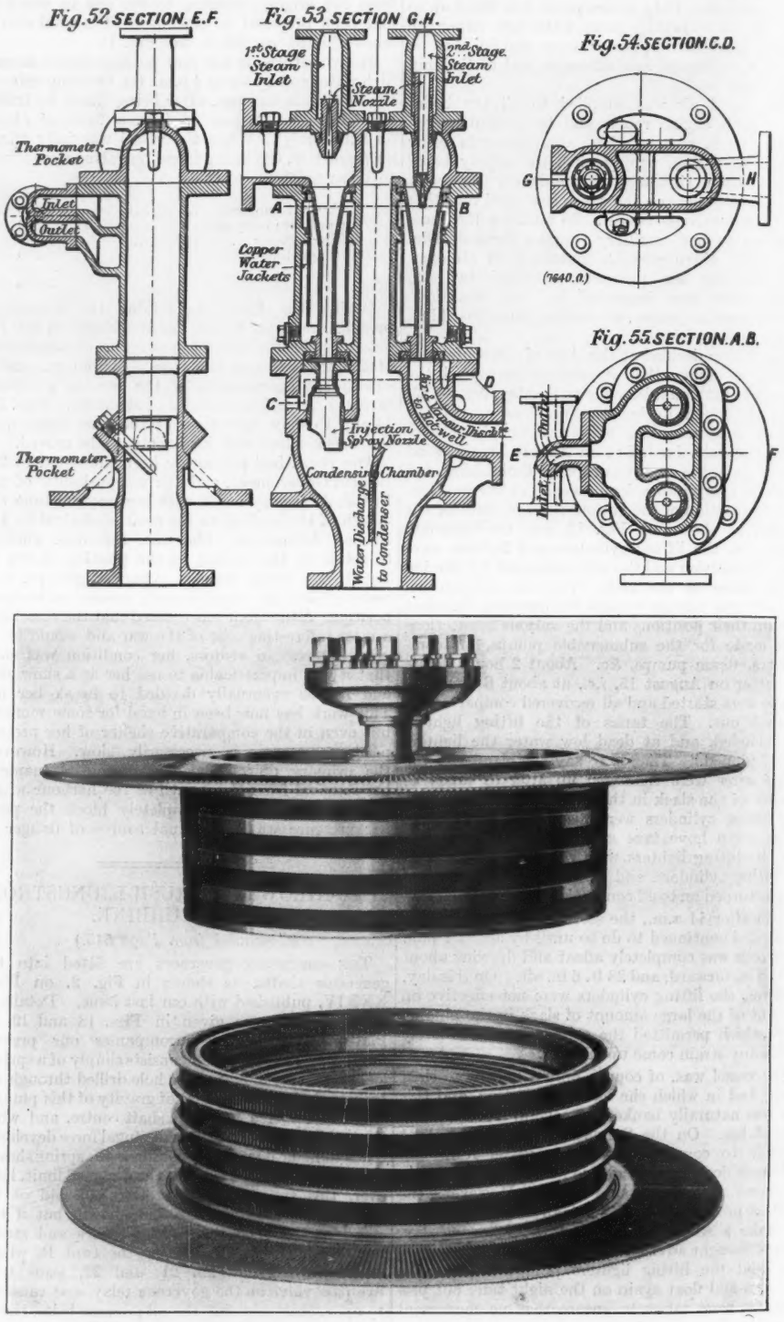


FIG. 60.

SINGLE METALLIC CRYSTALS.*

The Production of Single Metallic Crystals and some of their Properties.

By Professor H. C. H. CARPENTER, F.R.S. (Royal School of Mines).

THE following paper has been written at the invitation of the Council of the Iron and Steel Institute, following on a suggestion made by Dr. Hatfield at the last annual meeting, that it would be of interest to some of the members if Miss Elam and the author would prepare a paper dealing with the production and properties of single metallic crystals. It so happens that since the beginning of July Miss Elam has been engaged in work at the Cavendish Laboratory, Cambridge, arising directly out of the investigations referred to, and it has not, therefore, been possible to prepare a joint paper on the subject. With her consent, however, the author has undertaken to present an account of their investigations, and it must be understood that, so far as the experimental results are concerned, the following paper is, strictly speaking, joint work. Miss Elam, however, is not necessarily committed to the acceptance of the views stated therein, which are an interpretation of those researches.

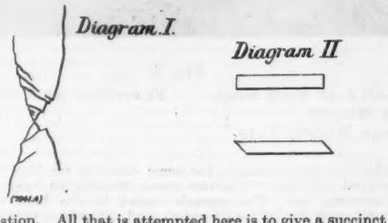
As a result of a large number of experiments extending over some years, Miss Elam and the author succeeded, about two years ago, in preparing very large crystals of the metal aluminium, and worked out the conditions under which such crystals could be regularly produced. The discovery, therefore, was not a chance one, but was simply the last of a series of experiments logically connected together. Emphasis is laid on this point because, whether the reasoning which led to this result be correct or not, it at any rate produced the desired result. Full information as to these researches will be found in the two papers specified in the footnote,* together with a review of other investigations bearing on the same subject. The present paper does not attempt to cover this ground so completely, and those who are sufficiently interested are referred to the papers in question. All that is attempted here is to give a succinct account of the results achieved, and a brief discussion of their theoretical aspects.

Metals and alloys are composed of aggregates of crystals. Attention is drawn to two of their characteristics. In the first place, they do not, as a rule, possess plane faces—that is, the external forms of crystals. They are joined together at boundaries which have been produced by the meeting of a number of crystals growing simultaneously, and are usually irregular in outline. It is generally assumed that crystallisation starts in the liquid metal or alloy from a number of centres, and proceeds with a velocity and in a manner characteristic of the metal and conditions under which it is being cooled. The resulting boundaries may approximate to plane surfaces, but are more usually curved and irregular. These crystals are called "allotriomorphic," to distinguish them from "idiomorphic" crystals, which do possess plane faces, and are characteristic of mineral substances and artificially prepared salts.

In the second place, they are usually very small and cannot be distinguished without the aid of a microscope. It is true that, in the case of large castings weighing many tons, crystals of several cubic inches capacity have been formed, and subsequently isolated. The great majority of metals and alloys, however, which have been cast and hot-worked, have from 150 to 300 crystals to the linear inch. This means that in all such cases there will be from 3,375,000 to 6,750,000 crystals in a cubic inch. Frequently, however, the size is even smaller, especially in the case of steels. The crystals are still more minute in severely drawn wires, and from figures given by Sykes* it appears that in molybdenum wire

FIG. 1. SHOWING DIMINISHING SIZE OF CRYSTALS WITH INCREASE OF STRAIN IN THE PARALLEL PORTION OF THE TEST-PIECES.

FIG. 2. SHOWING VARIOUS TYPES OF FRACTURE OF SINGLE CRYSTALS IN THE PARALLEL PORTION OF THE TEST-PIECES.



* Paper read at the meeting of the Iron and Steel Institute, Thursday, May 10, 1923.

* "Crystal Growth and Recrystallization in Metals," ENGINEERING, vol. cx, page 385 *et seq.* "The Production of Single Crystals of Aluminium and their Tensile Properties," Proceedings of the Royal Society, 1921, vol. c., A, pages 329–353.

* Bulletin of the American Institute of Mining and Metallurgical Engineers, vol. ii, No. 6, February, 1921.

there may be as many as 5,000 to the linear inch. This corresponds to a total of 125,000,000,000 crystals per cubic inch.

The properties of metals and alloys are the properties of these aggregates of minute crystals. Sauveur* was the first investigator to show, about eleven years ago, that by carefully straining and subsequently heating metals much larger crystals can be produced, and author's laboratories some years ago, stretched aluminium sheet to various degrees, and found on heating that up to a certain point deformation had no effect. Beyond this large crystals were formed, and as the deformation was further increased the crystal size was diminished.

About two years ago we succeeded in converting the whole of the parallel portion of aluminium test-pieces, whether in the form of sheets or bars, into a single crystal, reference to certain results established in the paper on "Crystal Growth and Recrystallization in Metals," already referred to. These results are:

1. In the absence of a change of phase, neither crystal growth nor recrystallization will take place in a metal unless it has been plastically deformed and subsequently heated to a certain minimum temperature and for a certain minimum time.

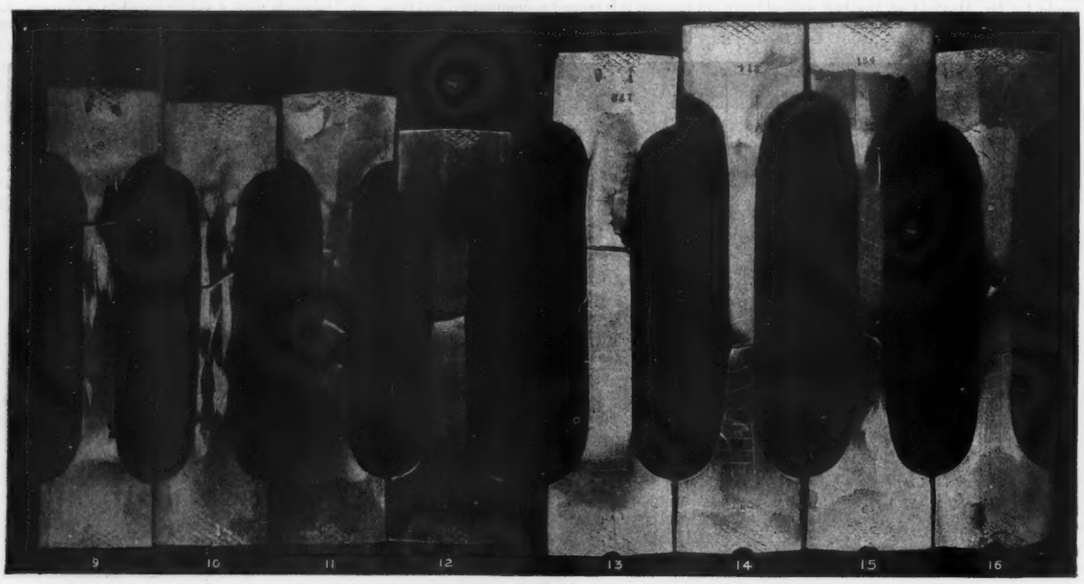


FIG. 3. SHOWING VARIOUS TYPES OF FRACTURE OF SINGLE CRYSTALS, EXCEPT IN THE CASE OF No. 12, WHICH CONSISTS OF THE USUAL NUMBER OF SMALL CRYSTALS (ABOUT 3,500,000 IN A CUBIC INCH).

FIG. 4.

No. 17 SHOWS THREE TWIN CRYSTALS—ONE AT EACH EDGE AND THE THIRD IN THE MIDDLE.
No. 18 SHOWS THE "STEP-UP" IN THE MIDDLE TWIN.

FRACTURES OF TWO CRYSTALS (END TO END IN THE PARALLEL PORTION OF THE TEST-PIECE).

suggested that there was a critical stress which produced the largest crystals. As subsequent events have shown, this suggestion is perfectly correct. Subsequently other investigators, notably Rüder, Chappell, Jeffries, and Hanson, showed that if a metal was locally deformed and then heated exceptionally large crystals were formed at some distance from the point at which the strain is severest. Seligman and Williams,† working in the which indeed extended for some distance up into the curved shoulders of the test-pieces, forming an irregular boundary line. The crystals varied in size from 0·5 cubic inch to 2·0 cubic inches, and it has been possible to compare some of their properties with those of the aggregates of small crystals of which this metal is usually composed. Experiments have also been carried out with silver, copper, and iron, but with less success, although in all three cases it has been possible to grow crystals very much larger than those contained in the original metal.

The steps which have led to the production of these very large crystals cannot be understood without a brief

2. The largest crystals are always formed at the minimum stress requisite to produce growth, which minimum is determined by the temperature of heating.

3. The lower the temperature of heating, the greater the stress required to produce the largest crystals obtainable at that temperature.

4. There is no gradual increase in size from the original crystals up to the largest; the latter appear to form directly from them.

5. Test-pieces of alumin um strained and heated at a low temperature, which nevertheless is sufficient completely to soften the metal, *e.g.* at 350 deg. C., show no

* Proceedings of the International Association for Testing Materials, Sixth Congress, vol. ii, No. 6, 1912.

† ENGINEERING, vol. cvi, page 448.

crystal growth at that temperature. Nevertheless, if subsequently heated at a higher temperature, they produce large crystals equal in size to those normally produced at that temperature for the same degree of strain.

6. In our experiments growth always took place by boundary migration, and not by coalescence.

7. Crystals can both grow and be grown into at one and the same time.

8. A large crystal may grow at the expense of a small one, and a small crystal may grow at the expense of a large one.

9. Neither similarity nor diversity of orientation affects the growth of one crystal into another.

It will be seen from this that in the production of large crystals of aluminium, the adjustment between mechanical strain and temperature of heating is extremely important.

This point is clearly illustrated in Fig. 1, which shows how the crystal size may be varied in aluminium according to the degree of strain. The eight test-pieces shown, after a preliminary heat treatment to remove work-hardness and render the crystals equiaxed, had been subjected to degrees of strain varying from 2 per cent. to 10 per cent. extension on 3 inches of the parallel portion of the test-piece. After this, they were all heated to 550 deg. C. and kept there for six hours. Finally they were etched in a 10 per cent. solution of caustic soda. It will be seen that the crystals in the test-piece extended 2 per cent. are very coarse, and that as the strain is increased the crystal size diminishes, until at 10 per cent. it has become quite small. But there is a further point to be noted, viz., that in all the eight cases shown large crystals have also formed in the broad heads of the test-pieces where the strain must have been less.

We have studied the structural changes produced in a crystal aggregate by deformation followed by heat, very carefully. They may be summarised broadly in the following way: The first effects of strain are slight. They are revealed by the presence of slip-bands, and, in some cases, twinned crystals. The former are completely, and the latter to some extent, removed by heating. No change is observed in the shape of the crystals. The boundaries appear unaffected, and, apart from twinning, there is no change in orientation. Thus far, only the interior of the crystals is affected. Somewhat greater deformation, however, followed by heat, produces actual crystal growth, and at this stage the boundaries of the crystals become active. The activity is shown in the capacity of the growing crystal to push forward its boundary in certain directions, thus invading other crystals, but even at this stage the orientation of the growing crystals is maintained. That of the crystals grown into is of course destroyed, unless it happens to be the same. A still greater deformation produces the third stage, which appears to take place exclusively in the boundaries of the deformed crystals. It is here that new crystals are born, indicating the destruction of the original crystals, and the production of a new orientation. Whereas, therefore, the early effects of deformation are shown only in the interior of the crystals, the later ones appear to take place entirely at the boundary. Accordingly, it will be seen that, from the point of view of producing large crystals from an aggregate of small ones, the intermediate degree of strain just referred to is the important one.

The Production of Single Crystals in Aluminium Sheet.

The problem which we set ourselves was to convert the crystals in the parallel portion of a test-piece 4 in. by 1 in. by 0·125 in. into a single crystal. These test-pieces were machined from a hard-rolled aluminium sheet and subsequently heated. After this treatment, which produced complete recrystallisation, there were about 150 crystals to the linear inch. Calculation shows, therefore, that the total number of crystals contained in the parallel portion of the test-piece was about 1,687,000. The experiments have been carried out with metal of the highest purity obtainable (99·6 per cent.). In order to convert the parallel portion of these test-pieces into a single crystal three treatments are necessary, two of them thermal and the third mechanical. The sheet as received was in the cold-rolled condition, the crystals being very much elongated and worked into one another. It had first to be heated, so that it might be completely softened and new equiaxed crystals of approximately uniform size produced. It had next to be strained to the required amount, and finally it had to be heated so that the potentiality of growth conferred by strain could be brought fully into operation. The details of these three treatments are summarised in the following paragraphs:

(1) *The Temperature and Time of Heating before Stressing.*—The most suitable temperature was found to be 550 deg. C., and the time six hours. If the heating was continued longer large crystals formed on the surface of the sheet in many cases, and the test-pieces were rendered useless, because the stress subsequently applied produced a greater elongation, which was localised to a large extent in these crystals, and consequently the strain was not uniform. If heated at a lower temperature the crystals finally produced for a given load and elongation were similar, but the results were very variable.

(2) *The Stress applied and the Percentage Elongation caused.*—In the earlier experiments the method adopted had been to stretch the test-pieces in tension by a given amount, measured by means of dividers on 3-in. gauge marks. This method was not capable of very accurate adjustment, and was discarded in favour of pulling with a given load and then measuring the extension. The advantage of this method was that the strain was always constant, and the variations in elongation were very slight. Moreover, a large number of test-pieces could be stretched with ease and rapidity. The procedure finally adopted was to pull to some definite fraction of a ton per square inch, which would give approximately the required elongation. A load of 0·20 ton, i.e., 1·6 ton per square inch, gave an elongation of 0·8 per cent. on 3 inches. If such a test-piece was subsequently heated large crystals were produced, but some small surface crystals frequently remained unabsorbed, even after many hours heating at 550 deg. to 600 deg. A load of 0·30 ton finally proved the most suitable. This is equivalent to 2·4 tons per square inch, and gave an average elongation of 1·6 per cent. on 3 inches.

(3) *The Temperature of Heating after the Application of Stress.*—It was found that large crystals began to form usually at about 500 deg. C., or even lower in some specimens, but not until 520 deg. in others, although the treatment had been identical in both cases. It was also found that the lowest possible temperature at which growth took place at all was the most suitable for growing the largest crystals. Consequently each test-piece was placed in a furnace whose initial temperature was 450 deg. C., and the temperature raised at about 20 deg. to 30 deg. per day up to 550 deg. C. It was then subsequently heated for one hour at 600 deg. C. in order to complete the absorption of small crystals on the surface, which persistently remained at lower temperatures. This method proved on the whole to be the best, but even so, on an average not more than one test-piece in four is converted into a single crystal over the parallel portion, the boundaries at each end extending in an irregular manner into the wide heads. The time required for a single crystal to form from the 1,687,000 originally present can only be stated approximately, for it has been found to vary within tolerably wide limits, and, as just mentioned, some of the small surface crystals only disappear after fairly prolonged heating, but in the majority of cases the result can be achieved in from 72 hours to 100 hours. A test-piece is, of course, much more quickly converted into three or four large crystals than into one, since in the former case growth takes place simultaneously from several centres.

Certain variations of the above methods were subsequently tried, but none of them was found to give greater regularity of results, although some of them established facts which bear on the question of how single crystals are actually produced. Prolonged heating at a low temperature, or starting the heating from a low temperature, *e.g.*, 250 deg. C., and gradually raising it, was not found to affect the crystal size. It was established that if the test-pieces were more severely stressed the temperature at which the maximum crystal size was produced was lowered. It was therefore to be expected that, provided the temperature at which heating was commenced was sufficiently low, all the test-pieces within certain limits of stress should give the same sized crystals on heating. A series of test-pieces was stretched 1, 2, 3, 4 and 5 per cent., heated at 250 deg. C., and the temperature then raised to 550 deg. C. In the pieces stretched from 1 per cent. to 4 per cent., the number of large crystals produced was approximately the same, although certain differences were manifest. In that stretched 5 per cent., however, the crystals were much smaller, indicating that, however much the temperature

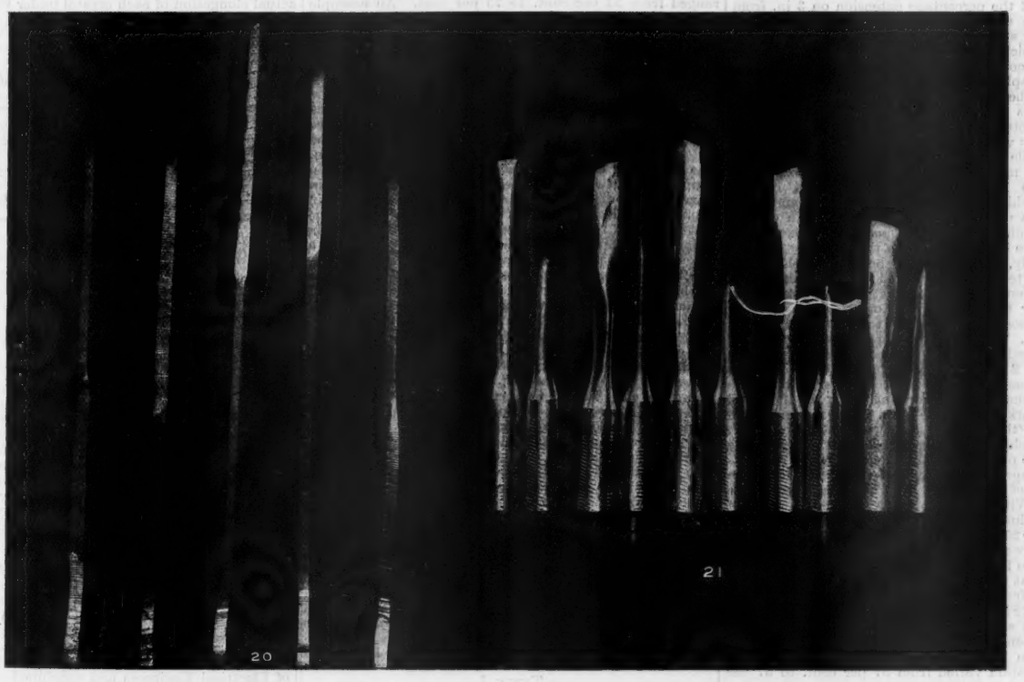


FIG. 5.

SIDE VIEW OF TEST-PIECES CONSISTING OF TWO CRYSTALS END TO END, BROKEN IN TENSION.

FRACTURED TEST-PIECES OF SINGLE CRYSTALS IN ROUND BARS, SHOWING HOW IN EACH CASE THE BAR DRAWS DOWN IN ONE DIMENSION AND PRODUCES A WIDE-SHAPED (DOUBLE-GROOVED) FRACTURE.

may be lowered, there is an upper limit to the stress which will produce the largest crystals.

If the optimum conditions for the production of a single crystal throughout the parallel portion of the test-piece are maintained, on an average one experiment in four is successful. There are, however, considerable variations from batch to batch, *e.g.*, in a given case 18 test-pieces, which had received as nearly as possible the same heat and mechanical treatment, gave the following results, which must be understood to refer only to the parallel portion of the test-piece 4 in. by 1 in. by 0·125 in. Two test-pieces consisted of one crystal, six of two crystals, five of three crystals, three of four crystals, and two of six crystals. In another batch, out of 20 test-pieces, seven consisted of one crystal, eight of two crystals, four of three crystals, and one of four crystals. The best result hitherto achieved has been in a batch where nearly half the test-pieces were converted into a single crystal over the length in question.

TENSILE STRENGTH TESTS.

When composed of small crystals (about 150 to the linear inch), as obtained by heating for six hours at 550 deg. C., the sheet gives uniform results on breaking. The ultimate stress varies from 4·5 tons to 4·7 tons per square inch, and the percentage extension on 3 in. from 36 to 38. The sheet necks slightly at the fracture, which is usually straight. This is the standard of comparison from which the behaviour of single crystals may be judged. Its condition may be regarded as "normal," and a photograph is given in Fig. 3, No. 12. The roughening of the surface, due to the large number of small crystals, is evident.

The values obtained in tests of specimens consisting of single crystals varied from 2·80 tons to 4·08 tons per square inch, while the extension varied from 34 per cent. to 86 per cent., measured on 3 in. These variations in properties were accompanied by differences in the method of stretching and the types of fracture, and these have provided a means of classifying them. In certain cases the mechanical properties, especially the extension, were found to be closely related to these characteristics. Speaking broadly, five types may be distinguished.

Type I.—The test-pieces narrowed in breadth gradually from the shoulders towards the fracture. The reduction in breadth near the fracture was often great, *e.g.*, the metal necked sometimes almost to a point (Fig. 2, page 579, No. 2). The sides (machined edges of the sheet) remained perpendicular, and the reduction in thickness was only from 2 per cent. to 3 per cent. Slip-bands were usually absent from the surface, but large slips were frequent near the fracture, forming steps on the sides and similar markings on the face. It was noticed in some specimens that a large slip occurred over one half, and this then held, while a similar slip took place on the other half. The process was then repeated until the test-piece broke (Diagram I). Slipping in this case took place in the direction of pulling, and at right angles to the plane of the sheet. With a view to following the distortion of the specimens during the test, some of them were ruled into squares (0·25 in.) by means of a fine needle point. The results showed that the squares became diamond-shaped (Diagram II) and that they had both narrowed and elongated, and at the fracture the lines at right angles to the axis were frequently bent at an angle of 45 deg. Nos. 1 and 2 (Fig. 2) are examples of this type, and No. 16 (Fig. 3) shows the change in the shape of the squares. The tenacity was found to vary in the case of seven tests from 2·9 tons to 3·9 tons per square inch, while the elongation varied from 57 per cent. to 67 per cent.

Type II.—In this case the test-piece remained broad, losing sometimes only 1 per cent. in breadth, but became very thin, with a uniform reduction of thickness of about 45 per cent. The sides tended to slope slightly in the same direction away from the perpendicular. Slip-bands on the surface were well marked, and their main direction was across the test-piece, *i.e.* at right angles to the axis. There was no necking at the fracture. The test-piece remained broad but drew down to a knife-edge, and then parted in a straight line, either at right angles to the axis or inclined at some other angle to it. If the test-pieces were marked in 0·25 in. squares before being pulled, the lines at right angles to the axis did not become inclined to the same extent as in specimens of Type I. They merely drew farther apart, while the position of the lines parallel to the axis did not alter. Although the squares were only lightly scratched on the surface with a needle point, the cross lines affected the internal fracture to such an extent that they were revealed on the opposite side of the test-piece by means of interruptions in the slip-bands (No. 7, Fig. 2). This phenomenon was only met with in specimens of this type, and is no doubt due to the particular direction of the slip-bands in relation to the stress. This type, therefore, shows slipping in the plane of the test-piece in the direction of the stress (Nos. 7 and 8, Fig. 2). Tenacity values obtained in these tests varied from 2·8 tons to 3·3 tons per square inch, and the extension from 47 per cent. to 74 per cent.

Type III.—In this case the test-piece both narrowed and thinned uniformly. There was no necking at the fracture which went straight across the test-piece, as in Type II, either at right angles to the axis or inclined at some other angle. A noticeable feature of this type is the sloping of the sides so that the section after pulling is no longer a right angle, but a parallelogram, with alternate acute and obtuse angles. The sideways slipping which causes the test-piece to take this form was entirely absent from Type I, and only slightly evident in Type II. It always occurs in this group, but not always to the same extent. Slip-bands were usually well marked, and were inclined to the axis at different angles. Squares marked on the specimens by a needle point both narrowed and elongated and became diamond-shaped, owing to the lines at right angles to the axis inclining towards it. Although similar in that respect to Type I, they differed in that the diamonds were more uniform in size and shape over the whole test-piece. In other words, the elongation was more general and uniform. This type, in contradistinction to the two previous ones, shows slipping in two main directions. It elongates in the direction of the stress, by slips nearly parallel with the plane of the sheet, and also at right angles to the plane of the sheet, but parallel with the axis. Inasmuch as these planes are not at right angles to the direction of the stress, there is always a sideways slip as the crystal endeavours to accommodate itself to it, and this accounts for the change in shape of the cross-section of the test-piece. There are greater variations in tensile properties in this than in any other group—the values for ultimate stress ranging from 2·9 tons to 4·1 tons per square inch, while the extension over 3 in. varies from 34 per cent. to no less than 86 per cent. Examples will be found in Nos. 3, 4, and 5 (Fig. 2).

Type IV.—This combines the qualities both of Type I and Type III, in that the test-pieces not only narrowed and thinned but, in addition, necked at the fracture. In all cases a sideways slip was evident. The values of tensile strength were remarkably uniform, varying from 3·1 tons to 3·3 tons per square inch. while the elongation ranged from 53 per cent. to 75 per cent. An example of this type is seen in No. 6 (Fig. 2), while Nos. 14 and 15 (Fig. 3) show the distortion of the 0·25 in. squares as a result of the strain.

Type V.—In this class are included all the test-pieces which produced twin crystals on being pulled. No signs of these were visible before stress was applied. In some cases only a few resulted, while in others the test-piece was twinned all over. In every case the test-piece buckled and crumpled to a certain extent, owing to the shifting of portions of the sheet into a twinning position. The slip-bands change in direction as they cross a twin boundary, and where the specimen had been marked in squares these also change direction sharply at the twin boundaries. Two types of twins were met with. The first resembled those produced in tin and zinc, although, owing to the large size of the crystals, they were on a much larger scale. They appeared like large fibres. The fracture across them was uneven and the thickness of the sheet at the fracture differed from twin to twin. Examples are given in Nos. 9 and 10 (Fig. 3). The second type of twinning observed was one in which the twinning planes were almost straight. Such a twin is shown at the top of the test-piece in No. 11 (Fig. 3). It appears as a narrow dark line starting at the shoulder of the test-piece and running up the centre of the broad end. Twins of this type also formed frequently on each edge of the test-piece. In a given case on one side the entire edge turned up, while the edge on the opposite side turned down. Nos. 17 and 18 (Fig. 4) show a part of the surface in which, in addition to twinning on the edge, a twin has also been formed at the centre. A section of this crystal (No. 18) shows how the twins at the edges turn in opposite directions, and also the step-up at the twin in the centre. Twinning planes across the crystal are all parallel. This type is similar to that produced by the well-known method of causing twinning in calcite. By pressing a knife on the acute angle of a calcite rhomb near the edge, a portion of the crystal can be bent right over, making a definite angle with the unaltered face. The tenacities in this class varied from 3·0 tons to 3·8 tons per square inch, and the elongation from 55 per cent. to 67 per cent. on 3 in.

The results are summarised in the following table :—

TABLE I.

Type.	No. of Tests.	Tensile Strength. Tons per Square Inch.	Elongation per Cent. on 3 in.
I.	7	2·9 to 3·9	57 to 67
II.	7	2·8 to 3·3	47 to 74
III.	15	2·9 to 4·1	34 to 86
IV.	8	3·1 to 3·3	53 to 79
V.	5	3·0 to 3·8	55 to 67
Sheet containing 150 crystals to the linear inch ..	5	4·5 to 4·7	36 to 38

STRESS TESTS OF TEST-PIECES CONSISTING OF TWO CRYSTALS.

Each crystal in a test-piece consisting of two or more crystals behaves according to one of the five types described above, provided that the whole test-piece at the point of fracture consists of a single crystal. A considerable number of specimens composed of two crystals were fractured in tension, and almost every combination of the five types was met with. In the majority of cases tested, the crystals occurred end to end in the test-piece, and fracture always took place across one or other of the crystals, but never at the boundary. The influence of one crystal in giving support to the other at the boundary was most marked, and its effect was often noticeable at a distance of 0·25 in. from the boundary. Reduction both in thickness and breadth was much less at this point, and the power to withstand deformation was considerably increased, especially where one crystal slipped to the left and the other to the right. The metal drew down on either side of the boundary and left it as a ridge, sometimes pronounced in thickness, at other times in breadth. In many cases the sheet looked as if it had been twisted in testing. It is not difficult, however, to account for these irregularities, when it is remembered in what different ways the single crystals extended in tension. The crystal which narrowed on pulling, in contact with the one which remained broad, tended to make the latter narrow also, with the result that it frequently wrinkled and twinned in the vicinity of the boundary. In its turn the crystal which remained broad tended to prevent the other from narrowing, and this produced a thickening. Figures of some of these test-pieces show the effects referred to above. In No. 19 (Fig. 4) will be observed three test-pieces in which the distortion at the junction of the two crystals is very manifest. No. 20 (Fig. 5) gives an edgewise view of five fractured test-pieces in which, in each case, the combination of types there included is mentioned. This shows very clearly the different extents to which the crystals have been distorted, and the influence of the junction.

In those cases where two crystals existed side by side in the test-piece fracture occurred across them, and one crystal frequently broke before the other. In this case the latter crystal continued to elongate until it also broke, with the result that when the test-piece was subsequently put together there was sometimes a gap of 0·25 in. between the fractured halves of the first crystal. Tests have been carried out on eighteen test-pieces consisting of two crystals. When the test-piece was marked in 0·25-in. or 0·5-in. squares before pulling, it was possible to measure the elongation on 1 in. in each crystal. These are not strictly comparable, as one of them includes the fracture. In one case, however, the specimen broke outside the gauge marks, and the figures represent the actual elongation of each crystal under the same load :—

Total Elongation on 3 in.	Crystal No. 1 on 1 in.	Crystal No. 2 on 1 in.
49 per cent.	71 per cent.	25 per cent.

TABLE II.—*Test-Pieces consisting of Two Crystals.*

Tensile Strength. Tons per Square Inch.	Percentage Elongation on 3 in.	Type of Crystals.		Percentage Elongation of each Crystal on 1 in.	
		Fractured	Other.	Fractured	Other.
3·1	55	IV.	III.	61	52
3·0	38	II.	II.	67	29
3·1	63	V.	II.	71	63
3·2	50	I.	II.	86	29
3·1	51	II.	II.	81	17
3·5	55	II.	III.	94	17

(*To be continued.*)

UNITED STATES AUTOMOBILE PRODUCTION.—Automobile production in the United States increased in March and was the highest on record, exceeding by 64,006 cars and trucks the high production of last June. Output of passenger cars increased from 254,650 in February to 318,424 in March, and truck production from 21,815 in February to 34,593 a total of 353,017 in March. Production for the first quarter of 1923, on the basis of figures now available, shows, says *The Iron Age*, New York, 796,780 passenger cars and 75,785 trucks, a total of 872,565 vehicles.

BRITISH ENGINEERING STANDARDS ASSOCIATION.—A tentative British Standard Specification for insulating oils for use in transformers, oil switches and circuit breakers (Publication No. 148—1923) has just been issued by the association. This specification is the outcome of an extensive research undertaken in the first instance by the Research Committee of the Institution of Electrical Engineers and continued by the Electrical Research Association, when that body was formed. The association has issued this as a tentative specification in the first instance, as the method of conducting the tests are at present undergoing further investigation, every effort being made to simplify the latter as much a possible. The Institution of Petroleum Technologists is also preparing methods of testing oils for the ordinary physical properties, such as viscosity, flash point, &c., which it is hoped will be available for use in connection with this specification. This is the first British Engineering Standards Association specification based on the work of the British Electrical and Allied Industries Research Association, and illustrates the very great value of such a body to the industry. Copies may be obtained from the offices of the British Engineering Standards Association, 28, Victoria-street, London, S.W. 1, price 1*s.* 2*d.* post free.

BRITISH EMPIRE PATENTS.—A deputation from the British Science Guild, consisting of Lord Askwith (the president of the Guild), Lord Avebury, Mr. Hunter Gray, K.C. (chairman of the Guild's "Inventions and Patents" Committee), Sir Robert Hadfield, Sir Trevor Dawson, Sir Richard Gregory, Mr. A. A. Campbell Swinton, and Lieutenant-Colonel W. O'Meara (hon. secretary of the Guild), waited upon Lieutenant-Colonel A. Buckley (Parliamentary Secretary to the Department of Overseas Trade), with whom was Mr. W. Temple Franks (Comptroller-General of Patents), at the House of Commons, on Tuesday evening last, the 1st inst. The deputation was introduced by Lord Askwith, and strongly urged that the necessary steps should be taken as early as possible by the Government to secure effect being given to the provisional scheme for an Empire patent drawn up at the British Empire Patent Conference held in London in June of last year. The scheme in question provides that a patent issued anywhere within the British Empire shall extend to the United Kingdom, or to any of the Self-Governing Dominions, or to India, upon registration in the particular territory in which protection is desired. (See Stationery Office publication: "Report of the Conference held at the Patent Office, London, from June 12, 1922, to June 23, 1922.") The proposals were sympathetically received by Colonel Buckley.

INDUSTRIAL NOTES.

THE average quarterly tonnage of coal raised per man employed in 1913 in British collieries was 64·7 tons, and the earnings per man 20*l.* 9*s.* 9*d.* The corresponding figures for the four quarters of 1922 were as follows: first quarter, 56·5 tons and 34*l.* 2*s.* 9*d.*; second quarter, 51·9 tons and 29*l.* 15*s.* 7*d.*; third quarter, 57·2 tons and 29*l.* 14*s.* 2*d.*; and fourth quarter, 60·4 tons and 31*l.* 9*s.* 10*d.* The delegate conference of the Miners' Federation is announced to be held in Blackpool on the 30th inst., when the Wages Agreement will come up for consideration.

Speaking last week at the annual meeting in London of the Mining Association of Great Britain, Mr. Evan Williams, the president, said there seemed to be in some quarters an idea that the Wages Agreement was all to the advantage of the owners. The fact was that whereas the owners, under the Agreement, should have had 15 per cent. of the balance of proceeds over costs other than wages during 1922 (85 per cent. going to wages), they had not received an average of more than 7 per cent., taking the country as a whole, and in no district more than 14 per cent. He re-stated the policy of the coalowners to take such prices as they could get from slowly recovering industries, and not to risk raising the price of everything by unduly raising the price of coal. That was why they refused the demand of the Federation to the effect that the price of coal should be raised by 3*s.* 4*d.* over the country as a whole, in order to increase the minimum wage. He added that the real solution of the problem of wages was a return to the eight-hour day. The miners wanted a wage of 48 per cent. above the standard. On the basis of the September figures, not a particularly good month for output, the eight-hour day would have given a wage about 46 per cent. above the standard, instead of about 24 per cent. as it was under the seven-hour system. One very disquieting feature of the improved coal situation was that when wages and opportunity for work began to increase, in South Wales for instance, the number of men who disqualified themselves by voluntary absenteeism from receiving the subsistence wage ran into 5,000 or 6,000 per week. In such circumstances, much as the owners would like to see the position improved, they felt the means of improvement lay within the power of the men themselves.

The Brussels journal, *L'Echo de la Bourse*, comments upon a scheme which the Belgian Works have in view to make up for the present lack of labour in Belgium. The intention is to arrange for the immigration into the country of Polish workmen, the wages of whom would be 20 francs per day for the skilled men, 17 francs for the labourers, the travelling expenses to Belgium being paid to the immigrants, also their return fare after a twelvemonth. This foreign labour competition is not to the liking of the Belgian trade union leaders. These, however, cannot gainsay that Belgian labour, formerly abundant, is now lacking in numbers, and has to be made up. The cause of the deficiency, according to the Belgian journal, is the rigid enforcement of the eight-hour day, which has considerably reduced output, and the constant exodus of Belgian workmen to France, where a man can work, on an average, ten hours per day, where there are no out-of-work funds to fall back upon, and where the unions have much less prestige and influence. The men who have left and continue to leave for France are the honest, deserving, conscientious, thrifty "workers," who are desirous of securing for their family a maximum of well-being, even at the cost of greater exertion on their part. The trade unions have succeeded in compelling the payment of an equal wage to everybody; the remiss operatives are paid as much as the most active, and the latter, weary of being placed on the same footing as any young bunglers, or at being prevented from honestly working longer hours, "clear out."

The *Iron Trade Review*, Cleveland, Ohio, refers to a recent revision of the United States Imperial Court, declaring unconstitutional the act of Congress fixing a minimum wage for women and girls in the District of Columbia, and says that this decision is inconclusive from a legal standpoint. The Court divided 5 to 3, and had Justice Branders participated, he would have brought the minority up to 4. The act invalidated, was one creating a commission and empowering it to fix, from time to time, a minimum wage for women and girls in various occupations at Washington. The majority opinion held that the act interfered with the private right of contract; the minority that if Congress had the right to legislate concerning conditions of employment, it could also legislate as to wages. From the practical standpoint, the decision will be acclaimed as loudly by employers and the vast army of salaried men as it has been denounced by Samuel Gompers.

In the matter of the shipbuilding dispute, the Shipbuilding Employers' Federation made at the end of last week the following announcement: "The Federation of Engineering and Shipbuilding Trades having intimated that the Joiners' and Plumbers' Societies accept the national overtime and nightshift agreement signed by the said Federation on March 22, the notices terminating employment, in so far as they relate to the members of these two societies, are withdrawn." The Boilermakers' Society have endeavoured to evade all engagement on their part by virtue of the agreement, and have continued to argue on questions of form and dates. Their action is answered by a statement issued last Monday by the Shipbuilding Employers' Federation in which they state that ". . . the Federation of Engineering and Shipbuilding Trades has acted on behalf of all its constituent members and has been accepted by the employers as so doing. This procedure was followed exactly in the recent agreement on overtime and night shift, and the boilermakers' refusal to accept the agreement signed on their behalf by the Federation is a challenge to collective bargaining."

The Negotiating Committee of the Craft Unions met in London on Monday to further discuss the railway companies' scheme for the reduction of the railway shopmen's war bonus. It is understood that the committee sent a reply to the companies rejecting any further attempt at reduction. A meeting with the companies took place on Tuesday, when the latter asked the committee whether the craft unions were prepared to submit the question to arbitration. The latter replied that they were against arbitration and in favour of direct negotiation with the companies.

THE CERAMIC SOCIETY.

REFRACTORY MATERIALS SECTION.

THE spring meeting of the Refractory Materials Section of the Ceramic Society was held at the Town Hall, Bournemouth, on Thursday and Friday, May 3 and 4. In the regretted absence, owing to illness, of Lieutenant-Colonel C. W. Thomas, Mr. W. J. Gardner was voted to the chair, but, after the business meeting with which the second day's proceedings commenced, the new president of the society, Mr. J. Holland, took the chair. On Thursday afternoon a visit was paid to the clay mines of Messrs. Pike Brothers at Wareham, and in the evening members and their friends assembled at the Grand Hotel for the usual dinner. On Friday afternoon the respective works of Messrs. Sharp, Jones and Co., Limited (Bourne Valley Pottery and Rock Concrete Tube Works), and of Messrs. T. Wragg and Sons, Limited (South-Western Pottery, Terra Cotta and Brick Works), both at Parkstone, were visited.

The first paper, read by Dr. Scott, in the unavoidable absence of the author, Mr. H. Dewey, F.G.S., was on "*The Geology of the Bournemouth District.*" In the area extending from Wareham to Christchurch, and from the Isle of Purbeck northward to Wimborne, apart from recent deposits and pleistocene gravels and brick-earth, the only geological formations represented are the eocene (tertiary) and cretaceous. The whole forms part of the Hampshire Basin, as a very shallow depression bounded by two ranges of downs, the more southerly of which is interrupted between the white chalk cliffs of Old Harry and the Needles (Isle of Wight). The axis of the basin lies nearly parallel with the Solent. The chalk, more than 1,100 ft. thick, forms a continuous layer beneath the sands, loams and clays of the New Forest and Bournemouth districts. The clays immediately overlying the chalk belong to the Reading Beds and the London Clay, and are worked for making red bricks, pavers, drain pipes and tiles, at several localities. Above these occur the sands and clays of the Bagshot Sands formation, which constitute the cliffs that extend from Poole Head to Bournemouth, and contain the beds of clay worked for the manufacture of pottery, &c. The lowest or pipe clay division of the Bagshot Sands forms only an irregular patch of ground west of Poole Harbour, around which the pipe-clays are best developed. Poole clay has been worked for certainly more than 250 years.

The beds overlying the Poole pipe-clays have been described as the Bournemouth Freshwater Beds, which consist of white and yellow sands with lenticular masses of finely laminated carbonaceous clay or loam and some rather impure pipe-clay. They may attain a total thickness of 400 ft., and above them are the Bournemouth Marine Beds (including the Boscombe Sands at the top), which may be 300 ft. to 400 ft. thick.

The chines which form the characteristic feature of this coast present various stages of growth from the merest beginning (at Meyrick Steps) through vigorous childhood (at Honeycombe Chine) to old age (in the valley of the Bourne). They invariably have a small stream down their centre, and originated from the activity of these streams.

Mr. A. S. E. Ackermann, B.Sc., next delivered a lecture on "*The Physical Properties of Clay.*" He was severely handicapped in having to present the chief results of more than five years' work in so short a time. Most of the work has been done on a small scale, but small-scale pile experiments have been repeated in China on a large scale, and six conclusions have been confirmed by the results. Apart from that, Mr. Ackermann contends that all natural laws are true equally on a small and a large scale. The clay used mostly for the experiments was London clay. Colloid material in clay increases its plasticity and addition of tannin and similar substances is beneficial in this direction. Clay particles are extremely fine, being less than 0·002 mm. in diameter. Some idea of its fineness may be gathered from the statement that in 1 gramme of material the total surface of the particles is 590 sq. cm. in the case of coarse sand, 1,900 sq. cm. in loams, and 4,220 sq. cm. in clays. But fineness of grain alone does not give clay its characteristic properties. Thus precipitated chalk, which is much finer than chalk pounded up and sifted, through a 200-mesh sieve, showed no plasticity. Chalk is not hydroscopic, but clay is.

The author investigated the penetration of clay by tapered bodies, such as a pyramid on a square base with the point directed downwards, and embodied the results in curves showing the relations between penetration and load, volume of displacement and load, area of the four triangular sides and load, percentage of water and pressure of fluidity, work done in causing penetration and percentage of water, &c. The curves representing the relation between penetration and load for clay with different proportions of water were proved to be parabolic curves.

Among the conclusions reached from the results of the experiments are the following. For tapered bodies gradually forced into clay the load necessary to produce a given penetration is proportional to the area of the surface of contact between the clay and the body. The load to produce a given penetration is very much greater the less the percentage of water (and other volatile matter) in the clay. The speed of penetration becomes 10 times as great at a certain critical load, and this load is the pressure (or rather stress) of fluidity. (A similar critical load has since been found for metals.) Thus clay containing a definite percentage of water, and at a definite temperature, has a definite pressure of fluidity, and when this pressure is reached and maintained the clay yields indefinitely as a dense viscous fluid, unless it be restrained from flowing or caused to rise so as to produce a statical head of clay. The pressure of fluidity is independent of the depth and depends solely on the percentage of water in the clay and the temperature of the clay, increasing with lowering of either. For equal depths, tapered piles support a larger load per unit volume of the pile than piles having parallel sides, and to increase the resistance of piles they should be corrugated as well as tapered. For a given quantity of material of which to make piles a large number of small piles is more efficient than a smaller number of large ones. The resistance to penetration is considerably greater the lower the temperature of the clay. The tensile strength of the clay used was greater when it was raw and dry than when it was baked. The author has fully confirmed the statement attributed to Coulomb that clay is elastic. The tensile strength of clay increases as the water content of it decreases. The work done per cubic centimetre to cause displacement by means of tapered bodies is constant for any given set of conditions; this is equivalent to stating that for tapered bodies and a given percentage of water in the clay the surface of contact is directly proportional to the load causing penetration. The pressure of fluidity appears to be considerably reduced if the clay has once been allowed to become thoroughly air dried and is then wetted and puddled. The pressure of fluidity was decreased about 25 per cent. as a result of boiling the clay. Even under considerable tangential stress clay containing 25 per cent. of water behaves as a solid and not a fluid.

The addition of an artificial head to the top surface of clay increases its pressure of fluidity, but, even when the addition is as much as 200 per cent. of the actual head, the increase of the pressure of fluidity is only about 7 per cent. when the clay contains 25 per cent. of water. When clay is discharged under pressure through sharp-edged circular orifices, the rate of discharge increases more rapidly than the increase of pressure, and ultimately there is a phenomenon analogous to the pressure of fluidity, which has been called the critical pressure of extrusion. When the orifice has been plugged for a couple of hours and is then unplugged, the discharge is considerably less for some time than it was immediately before the plugging. The discharge per square centimetre of orifice for a given pressure is less the smaller the orifice. The initial pressure necessary to cause the discharge to begin increases considerably as the diameter of the orifice is decreased. The greater the pressure the greater the increase of discharge per square centimetre of orifice when changing from a small to a larger orifice. It does not seem to matter whether a sphere or disc of the same diameter is used for determining the pressure of fluidity, and in determining the pressure of fluidity by means of a disc or sphere the result is independent of the diameter of the disc or sphere within a considerable range.

The author has suggested that in the case of clay the work done per cubic centimetre displaced might be used as a measure of its plasticity, for the pressure of fluidity may be determined both easily and accurately, which is not the case for either the tensile strength or the elongation of clay. The work done in kilogramme-centimetres per cubic centimetre of clay displaced is numerically equal to the pressure of fluidity in kilogrammes per square centimetre.

The paper by Mr. G. M. Gill on "*The Use of Refractory Materials in Gas Works,*" which followed Mr. Ackermann's lecture, will be published later in ENGINEERING.

(To be continued.)

IRON AND STEEL IN SOUTH AFRICA.—Publicity is given in *The South African Mining and Engineering Journal* to a recent agreement entered into between the South African Iron and Steel Corporation, Limited, and the Union Steel Corporation, Limited, which provides for the erection of large blast furnaces and steel furnaces at Pretoria. If this programme is carried out, the news further states, it is very doubtful whether iron smelting on a large scale will be undertaken anywhere else in South Africa for very many years to come.

SAFETY DEVICES FOR CIRCULATING SYSTEMS.

CONSTRUCTED BY MR. C. L. STOKOE, ENGINEER, WALLSEND-ON-TYNE.

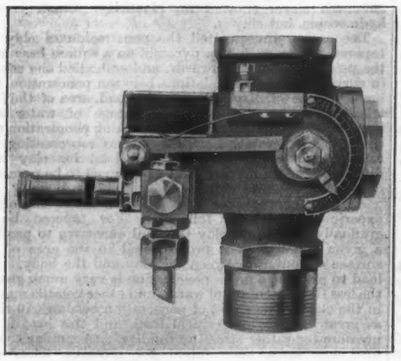


FIG. 1.

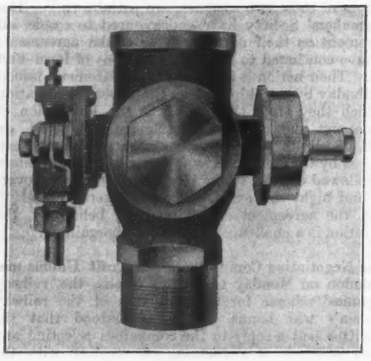


FIG. 2.

FIGS. 1 AND 2. SPRING-CONTROLLED TYPE.

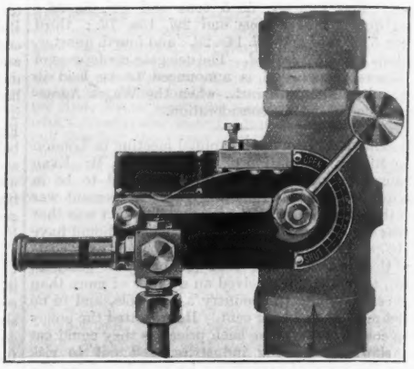
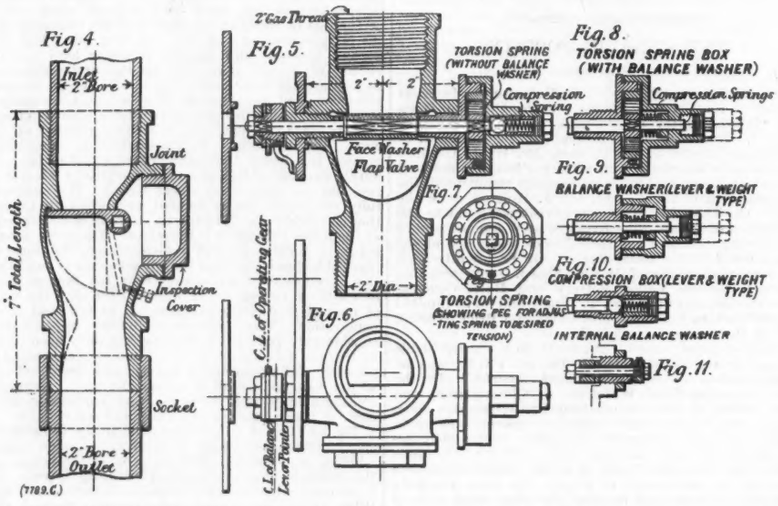
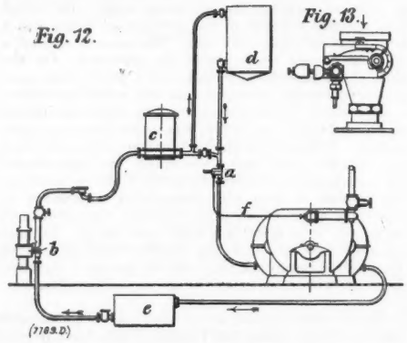


FIG. 3. WEIGHT-CONTROLLED TYPE.





THE safeguarding of the cooling-water systems of gas engines, air compressors and other industrial plant is a subject of considerable moment. In large plants the quality of maintenance and attendance may usually be such that a breakdown from failure of a cooling-water circulating system is a comparatively remote possibility, but in smaller plants, in which attendance is not continuous, such a failure may well lead to cracked cylinders or other trouble before it is noticed. Even in large and well-attended plants the employment of some safeguard which will notify stoppage of such a circulating system is of great value. The same remarks apply equally to many lubricating oil circulating systems, particularly in reference to turbines and gearing.

The design of a self-contained and comparatively simple safety device applicable to circulating systems of all kinds is not altogether an easy matter, as questions of lay-out, nature of water supply and attendance, vary so greatly between different cases, and considerable interest attaches to the Monitor safety devices which we illustrate on this and the opposite pages, and which are constructed by Mr. C. L. Stokoe, of 114, Central Buildings, Wallsend-on-Tyne. The varied nature of the conditions with which these devices are adapted to deal is illustrated by the fact that they may be applied to the cooling-water supply systems of air compressors, oil and gas engines, electric controllers for large winders, transformers, &c., as well as to oil-cooling systems for large bearings, gearing and thrust blocks. Further applications cover washing-water circuits for gas plant scrubbers, water seals, sprayers for air washers for large alternators, brine circuits for refrigerating plants, and the continuity of supply of water to high-lift turbine pumps. The appliance is covered by patents.

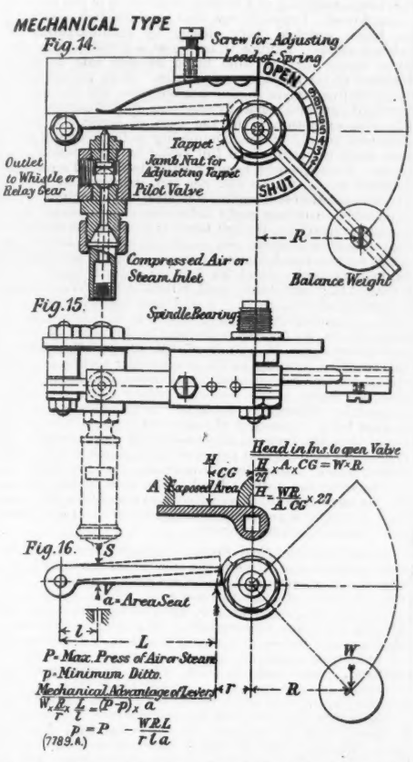
The Monitor valve is a device which is fixed in the supply pipe of the circuit which it is to safeguard, and in the event of a failure of cooling water flow, or in the event of the plant being started up without the cooling-water service being set in operation, will give an audible or visible indication of the fact. In many cases the device may be arranged to close down the plant if desired. The valve is built in two types—mechanical and electrical—but the essential valve part of the apparatus is the same in the two cases, the electrical and mechanical features being concerned rather with the indicating duties which the valve has to perform. The mechanical type is built in two forms, one being spring-loaded and the other loaded by a weight carried at the end of a lever. An example of a spring-loaded valve is illustrated in Figs. 1 and 2, and of a weight-loaded model in Fig. 3. These figures in conjunction with Figs. 4 to 11, which illustrate the internal arrangement of the valve proper, clearly indicate the main features of the device. Before turning to a description of the details, reference may, however, be made to Fig. 12, which illustrates an application of a Monitor valve to the lubrication system of a geared turbine. The valve *a* is placed in the oil circuit which flows from the pump *b* through the cooler *c* and the gravity tank *d*, through the valve to the turbine gear. The return circuit passes through the strainer *e* back to the pump. In this case the valve is arranged to give indication of stoppage of flow by blowing a whistle which is attached to the valve as indicated in the larger detail given in Fig. 13. A similar arrangement is shown in Figs. 1 and 3. The whistle in Fig. 12 is operated from the turbine steam supply, being connected up by the pipe indicated at *f* in the figure.

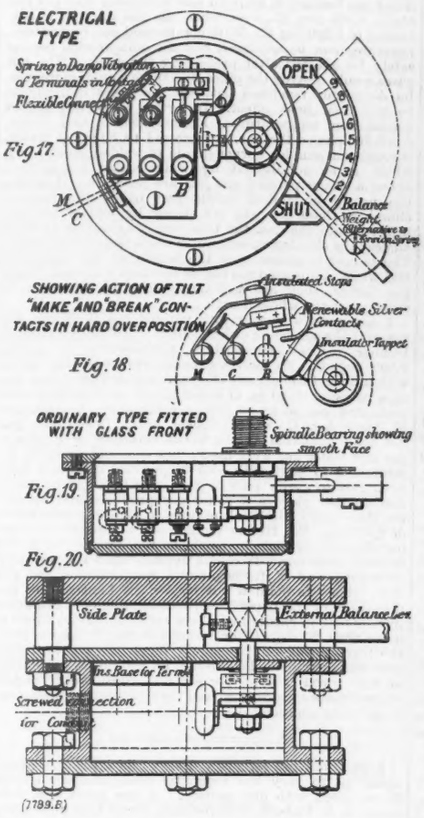
As the first condition for a safety device which is to safeguard flow is that it should be operated by flow, as distinct from pressure, it is necessary that whatever arrangement is adopted shall be capable of being operated by a very small head, and that very little head shall be lost in it. It is a simple matter to arrange that the valve itself shall move freely in the pipe in accordance with the flow, and it is in connection with the transference of the motion of the valve to the outside of the valve casing, for the purpose of operating the indicating device that difficulty may arise. Anything in the nature of a packed gland is likely to involve too much friction to be of any value. The question of leakage is, however, simplified by the fact that liquid under only a small head is being dealt with. As will be seen from Figs. 4 to 6, a flap valve is adopted in the Monitor gear. The flow of liquid tends to keep the valve open against the action of a weight, or spring, which tends to close it. The lever arrangement is shown in Fig. 3, while a valve fitted with a spiral spring is shown in Figs. 1, 2, 4, 5 and 6. The spring is carried in a circular box, and as shown in Fig. 7, arrangements are made for adjusting the tension. As the position which the valve takes up in the pipe is a function of the amount of water passing, the arrangements may be calibrated so that it serves not only to operate an alarm in case of failure of supply, but to indicate to the attendant if there is any partial failure. The calibrated scale is shown in Fig. 1. The appliance is not intended to act as a meter, and its indications are comparative only, but they serve as a useful check. The flap valve may be set to suit either horizontal or vertical flow, up or down.

The details of the valve spindle and its mounting are given in Figs. 4 to 11. As will be seen, plain bushes are used without packing to ensure freedom of movement, and the end position is maintained by faced washers with spring washers behind them, or by such an arrangement at one end balanced by a helical spring with a thrust ball at the other. Alternatively the helical spring bearing on a washer carried by a step on the spindle may be used. Various arrangements are shown in the figures. In addition to moving the valve and its spindle the alteration in flow is required to operate the alarm gear, and the arrangement adopted in the case of the mechanical model is illustrated in Figs. 14 and 15. As in the main valve itself the arrangement is designed to operate with as little effort as possible. It consists of a ball valve which is held down on its seat by a poppet, the upper pointed end of which lies in contact with the underside of a pivoted lever. The pressure of the steam or compressed air which blows the alarm whistle tends to lift this valve, and it is held down by a flat spring bearing on the upper

SAFETY DEVICES FOR CIRCULATING SYSTEMS.

CONSTRUCTED BY MR. C. L. STOKOE, ENGINEER, WALLSEND-ON-TYNE.





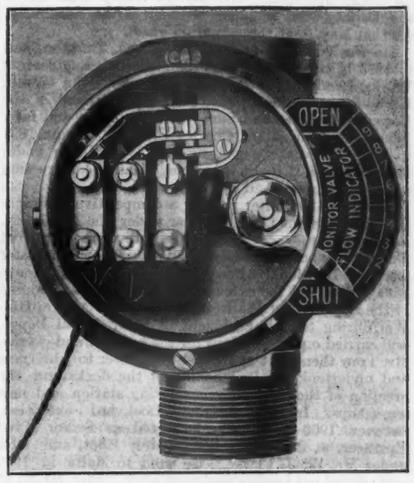


FIG. 21. ELECTRICAL TYPE.

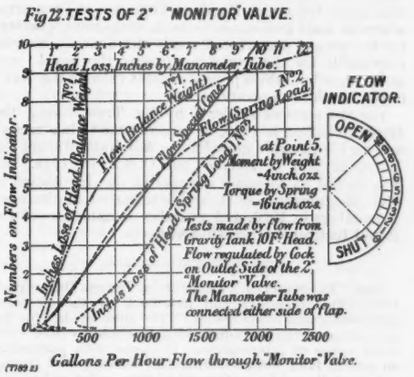


Fig 22. TESTS OF 2" "MONITOR" VALVE.
Head Loss, Inches by Manometer Tube:
Numbers on Flow Indicator.
Inches Loss of Head Balance Weight No 1
Flow (Balance Weight) No 1
Flow Special Cone No 2
Flow Spring Load No 2
Inches Loss of Head (Spring Load) No 2
at Point 5, Moment by Weight = 4 inch. ozs.
Torque by Spring = 16 inch. ozs.
Tests made by Flow from Gravity Tank 10 Ft. Head. Flow regulated by Cock on Outlet Side of the 2" "Monitor" Valve. The Manometer Tube was connected either side of Flap.
FLOW INDICATOR.
OPEN
SHUT
500
1000
1500
2000
2500
(7789.D) Gallons Per Hour Flow through "Monitor" Valve.

side of the pivoted lever. The boss of the weight lever arm, which is carried by the spindle of the flap valve, is formed with a tappet in such a position that if the flow fails and the valve moves to the shut position, the tappet lifts the pivoted lever and allows the ball valve to open, so that the whistle blows. The whole arrangement is clearly shown in Figs. 3, 14 and 15.

The electrical indicating gear offers a somewhat simpler problem than the mechanical one, as there is no difficulty in arranging an electrical contact which can be made or broken with very little effort. The arrangement employed is shown in Figs. 17 to 21. The flap valve spindle carries a tappet made of insulating material which, when the valve is shut, comes in contact with a curved spring arm and lifts it slightly, thus making a circuit which rings an alarm bell. The bell circuit is connected between contacts M and C, of Figs. 17 and 18, and it will be clear that when the curved spring arm is lifted by the tappet into the position shown in Fig. 18 connection is made between the contact carried by the curved arm and the outer contact carried by the shorter spring arm which is connected to terminal C. The actual contacts are silver tipped and are clearly shown in Fig. 17 and 18. It will be noted that the second contact carried by the shorter spring arm makes connection with a contact mounted on the terminal block B. These contacts are together when the flap valve is open and more apart when it closes. A lamp is connected in the circuit joining the terminal blocks B and C, and forms an additional alarm indicator, the lamp remaining alight so long as flow of liquid in the pipe is not interrupted. As will be seen a small flat spring carried by the longer arm bears on an insulated block carried by the shorter. This serves to keep the contacts well together and prevents sparking which might take place owing to vibration of the pipe in which the safety device is mounted. The contacts are surrounded by a casing which is furnished with a glass front as shown in Figs. 17, 19 and 21, but when the apparatus is to be used for mine works a complete gastight casing is used as shown in Fig. 20.

It will be clear that the restraining control on the movement of the flap valve, which is exercised either by the balance lever weight or the torsion spring, represents a certain loss of head in the apparatus, and should be kept as small as possible. A diagram representing the forces acting in the case of a 2-in. Monitor valve is given in Fig. 16. The exposed area of the valve in the closed position is 1·7 sq. in., and the centre of gravity of this area is $\frac{7}{8}$ in. from the centre line of the spindle. The balance weight is 3 oz., and acts at a radius of 2 in., and the additional allowance for bearing and washer friction at this radius is 1 oz. Since 1 cub. in. of water weighs $\frac{1}{27}$ lb., one has the equation :—

$$\frac{H}{27} \times A \times CG = W \times R$$

or

$$H = \frac{27 \times 4 \times 2}{1{\cdot}7 \times 16 \times 0{\cdot}875} = 9''.$$

That is a head of 9 in. of water is sufficient to open the valve. When it has opened a small amount, more valve area is exposed which balances the slightly increased effective radius of the balance weight as it moves up its arc.

The equation for the weight required to open the pilot ball valve is given in Fig. 16. This valve is kept down on its seat by the flat spring bearing on the lever and tends to open owing to the pressure of the air, or steam, which is used to operate the whistle alarm. This pressure assists the flap valve when the lever is lifted owing to failure of cooling water flow, and if the pressure falls more work is obviously required from the flap valve. The device is arranged so that the alarm will operate even with a considerable fall of pressure in the air or steam mains. With an air compressor there will usually not be much variation, but in the case of a turbine operating with steam at 250 lb. per square inch, it is considered desirable to arrange that the device shall still operate if the pressure falls to 130 lb. per square inch. The area of the ball valve exposed to the steam pressure is $\frac{1}{32}$ sq. in., and the mechanical advantage of the lever arrangement $\frac{R \times L}{r \times l}$ is 13, so that taking a difference of pressure of 120 lb. between maximum and minimum, the weight on the balance lever to meet the conditions would be

$$W = \frac{(P - p)\, a\, r\, l}{R\, l}$$

$$= \frac{(120)\ 1 \times 1}{36 \times 13} = \frac{1}{4}\text{ lb.}$$

It is found necessary to add an additional ounce to this figure to overcome friction. This case is an extreme one, and generally a difference of pressure of some 20 lb. or 30 lb. would probably be all that it is necessary to consider. A smaller ball valve having an exposed area of $\frac{1}{17}$ sq. in. may also be used. This reduces the size of the balance weight by more than half.

Some curves plotted from tests on Monitor valves are given in Fig. 22. The curves refer to two cases only, the first showing the flow and loss of head with a balance lever $2\frac{3}{4}$ in. long carrying a weight of $1\frac{1}{2}$ oz. at the end, and the second being controlled by a torsion spring having four times the effort at point 5 on the flow indicator that it has at zero. In the case of the lever valve the torque was a maximum at point 5 and a minimum at zero and 10, while in the case of the spring the torque was practically nil at zero and a maximum at point 10. In the case of the spring-loaded valve the curve is practically a straight line up to point 6, and by forming the flap valve casing, as shown in Fig. 5, to a special cone form, a straight line can be obtained throughout as indicated by the further curve shown in Fig. 22. Special Monitor valves to act as flow meters are constructed in this way.

INSTITUTE OF PATENTEES (INCORPORATED).—We are informed that special information has been received by this Institute in connection with patents in the Irish Free State, and that this information will be supplied to any of our readers, on application to the organising secretary, addressed 44, Great Russell-street, W.C. 1.

THE MEASUREMENT OF AIR FLOW: ERRATUM.—A printer's error occurs on page 481 of our issue of April 20, 1923, where in Mr. King's article on "The Measurement of Air Flow," column 1, line 27 from the commencement, the text should read $29{\cdot}62 \times \left(\frac{6}{2}\right)^2 \times \sqrt{6}$ instead of $29{\cdot}22 \times \frac{66}{22} \times \sqrt{6}$ as printed.

IRON IN CHINA.—Many iron mines have been discovered in Yunnan, according to the Chinese Government Bureau of Economic Information. About 20 mining companies have been granted registration and about 50 others are now being worked, but are not yet registered by the Ministry of Agriculture and Commerce. Since old methods are used to refine the iron ore, the annual amount of iron exported to other provinces is small.

THE LATE MR. GEORGE H. M. TREW.

AFTER more than a year's absence from business through a series of illnesses, involving the necessity for many operations, Mr. George Henry Male Trew, the Deputy Civil Engineer-in-Chief to the Admiralty, died on May 5, at the age of 56 years.

He was educated at Queen's College, Taunton, and in 1883 began a pupilage at the Millbrook Engineering Works, Landore, South Wales, under Mr. John Powell. He added to his experience in the department of the Borough Engineer and Surveyor of Swansea and later joined the staff of Mr. Charles E. Sayer. From 1891 to 1896 he was engaged by the War Office under Major Hellard, R.E., on the survey of land, construction of barracks, roads and drainage at Woking.

Early in 1896, after passing a competitive examination for Assistant Civil Engineer under the Admiralty, he entered the service. He was first employed at Devonport under the superintendent engineer, and later became Divisional Officer in charge of Plymouth breakwater and the extensive rock and other dredging of the Sound. He was Resident Engineer at Wei-Hai-Wei during the establishment of H.M. Naval Depot, and carried out the surveys for the harbour and works. Mr. Trew then went as Resident Engineer to Sheerness and undertook the lengthening of the docks and the erection of the electricity generating station and new workshops. In the Keyham Dockyard extension, between 1906 and 1909, he acted as Senior Civil Engineer, at first under Sir Whately Eliot, and later under Mr. W. J. Clarke. He went to Malta in 1909 and carried out further dockyard work, under Mr. G. P. Hayes, as well as completing the breakwater and the lighthouse on St. Elmo Arm. In 1913, Mr. Trew was appointed senior Resident Engineer at Cromarty, where he built gun emplacements, magazines, quarters for troops and constructed roads and a pier. He was responsible for the works comprising the naval base at Invergordon, which proved of great value to the Navy in the North Sea operations.

For the services rendered by Mr. Trew during the Boxer Rebellion in 1910, he received the China medal, and for his valuable work for the Admiralty during the European War he received the O.B.E. in 1918. He was elected an associate member of the Institution of Civil Engineers in 1899, and transferred to the class of members in 1920, and was also an associate of the Royal Institute of British Architects.

THE "ELECTRICIAN" ELECTRICAL TRADES DIRECTORY, 1923.—This directory and handbook of the electrical engineering and allied trades, "The Blue Book," for the current year, the forty-first edition, contains close upon 1,400 pages of information. It opens with particulars on patent laws both covering this country and foreign nations, followed by mathematical data, notes on lighting, testing rules, tables of import duties, detailed chapters on international telegraphs, on telephones, broadcasting, &c. Information is also given on a number of the British technical societies. A legal digest deals with the electric lighting and electricity supply Acts. The directory portion is in several alphabetical sections, a British section under names, a section according to trades and occupations, and Colonial, Continental, Asiatic, African and American sections. The book shows evidence of having been prepared with great care. Like the preceding editions it is issued by the *Electrician*, and is published at the price of 25*s.* net by Messrs. Benn Brothers, Limited, 8, Bouverie-street, E.C. 4.

MARKET FOR MOTOR CARS IN ARGENTINA.—The Commercial Secretary at Buenos Aires, in a memorandum on the market for motor cars in the Argentine Republic, states that it is estimated that there are approximately 75,000 motor cars in service in the Argentine Republic. During the five years 1910 to 1914, the number of motor cars imported amounted to 15,623, as compared with 40,640 for the five years 1916 to 1920. Whereas France headed the imports in the 1910–14 period, the United States have practically monopolised the market during the 1916–20 period, having supplied 98 per cent. of the demand. The reason for this is accounted for by the splendid organisation of the sales department of the American companies. Another reason for this preference for American cars in general is the fact that they are in every way more adapted to the features and conditions of Argentina. From information obtained in the trade the only advantage a British car holds over that of American manufacturers, is a lesser petrol consumption, but as the number of people who seriously consider this question is so small, the advantage is almost negligible. The main reasons for the preference given to American cars, will perhaps be better explained in the following manner: (1) Much cheaper selling price; (2) nicer looking lines or "finish"; (3) higher reserve of power—"quicker get-away"; (4) greater ground clearance; (5) better service for spare parts and repair parts, &c.; (6) more luxurious appearance. According to the trade, the great mistake with British manufacturers is that they build a car to last too long. The prospective buyer almost invariably prefers a car at a lower cost, which will run perfectly for anything from two to five years, and then buy another new car, with all the latest improvements, selling his old car at 30 per cent. to 50 per cent. of its original cost.

COMPRESSED GAS AND PRE-HEATED AIR FOR OPEN HEARTH FURNACES.

ACCORDING to various series of observations taken by G. Donner, of Duisburg, the temperature of the producer gas burning in an open hearth furnace does not rise above 1,800 deg. C., even when the gas mixture is pre-heated to 1,200 deg. C. With compressed gas, higher temperatures can be attained, but the compression cannot safely be effected after preheating the gases. The hot gases would destroy the pipes, and there would, moreover, be dangerous reactions between the gases detrimental to the final heat effect. In order to obtain higher combustion temperatures, Donner (Stahl und Eisen, April 26) passed the gas, compressed to 80 in. of water, through an annular burner (made of welded sheet iron), which is so subdivided by water-cooled pipes, that about a dozen parallel gas jets are produced. Leaving the nearly horizontal nozzle just inside the furnace chamber, these gas jets are struck by jets of hot air, injected into the gas, the two currents meeting at right angles; the circulating cold water keeps the burner intact. The burner is placed over the hearth at the one end, and while compressed gas flames are shorter than ordinary gas flames, they are sufficiently long in this case to sweep over the whole hearth.

Using such a burner with various gas mixtures, the gas and the air being either cold or warm before mixing, Donner reached combustion temperature of nearly 2,500 deg. C. So far his experiments have been made with a 3-ton furnace, and it would appear that a cold gas at a pressure of 80 in. of water mixed as indicated with preheated gas so as to give a combustion temperature of 2,000 deg. C. would answer best. Coke oven gas not being available at the works, mixtures of producer gas and water gas were used; but it would probably be preferable to start with coal to produce coke and coke oven gas, to gasify part of the coke in a gas producer and another part in a water gas producer and to mix the three gases, the final mixture to yield a temperature of 2,200 deg. C. Higher temperatures, through shortening the heating periods, would be too destructive to the furnace materials. It is not unlikely that the ordinary determinations of furnace-flame temperatures are too low; this was pointed out by Dr. H. Lent during the discussion of the paper. A thermocouple or a radiation pyrometer can hardly indicate a gas temperature which is more than 20 deg. C. or perhaps 30 deg. C. higher than the furnace-wall temperature. When the gas is drawn over the thermocouple, through an aspiration pyrometer at high speed (150 m. per second), considerably higher temperatures are observed and the real flame temperature is probably approached.

INFLUENCE OF IRON ON FAINT MAGNETISM.—Statements as to very low magnetic susceptibilities should be accepted with due caution. A few years ago, Professor O. E. Fribold, of Christiania, found that pure silver was faintly diamagnetic. Repeating these experiments last year, as stated in *Annalen der Physik*, with the purest commercial silver, containing traces of iron, he found a higher susceptibility than before, $0{\cdot}43 \times 10^{-6}$ c.g.s. unit, which fell off and changed into $-0{\cdot}08$ (same unit) as the field intensity increased from 83 c.g.s. to 4,200 c.g.s. units. Purified of the traces of iron by electrolysis, however, this silver showed a constant susceptibility of $-0{\cdot}17$ which was independent of the field intensity and did not change when the silver was fused in atmospheres of either nitrogen or oxygen. Silver is therefore faintly diamagnetic, and the previously observed paramagnetism was due to traces of iron which, other experiments prove, has a powerful influence when present in the uncombined state and when not forming mixed crystals with the metal. This was confirmed by fusing the purest silver with iron, and further by experimenting with various zinc-iron melts. These two metals form mixed crystals, and the influence of iron upon the magnetic susceptibility of the alloys or compounds formed was found to be very weak and independent of the field intensity. The ferromagnetic influence of iron comes out strongly when the iron is present as unbound metal.

ELECTRIC WATER-FLOW METER.—The water-flow meter which is known as "D B F" is practically a small dynamo provided with a propeller, driven by flowing water. The electromotive force generated is indicated or recorded by a galvanometer which may be calibrated in metres per second. The letters D B F stand for the three inventors, R. Dicks, S. Bitterli and R. Fischer, who describe their device in *Schweizerische Bauzeitung*. The instrument resembles a small torpedo, about 20 in. long; it is encircled by a strap by means of which it is suspended in the water. The metallic body is made strong to bear immersion to considerable depths, and consists of two portions fitting into one another. The front of the torpedo carries the two-bladed propeller outside and inside the shaft in roller bearing running in oil. The permanent field magnets are in the aft portion; the armature is simply a coil free of iron. At the highest probable water speed of over 4 m. per second the current generated would not amount to more than a few hundredths of a watt at a potential of 0·75 volt. The instrument has been calibrated in the hydraulic institute at Worblaufen, near Bern. It is very little influenced by temperature changes and will respond to flow in either direction. The dynamo vane is said to have answered in open water and in closed pipe systems, and is recommended also for recording the flow of gases. The advantage over ordinary vane and cup instruments is that it indicates the instantaneous rate of flow and not only the averages as marked by a counter which operates after a certain number of revolutions.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Though the local staple trades have not perhaps improved to the extent that was anticipated at the beginning of the year, a steady upward movement is evident, resulting in a weekly diminution of the total of unemployed. Prices of raw and semi-finished materials are being watched very closely by manufacturers of finished goods. Failure to arrive at a settlement in the Ruhr seems for the time being at any rate to have disposed of the hope of easier rates. More inquiries for future deliveries are in the market than was the case a fortnight ago, and generally speaking quotations are firm. The one exception is in the case of scrap. A more abundant supply of this commodity is forthcoming now that work is getting into full swing in the breaking-up yards. Consequently, heavy melting basic steel scrap has declined by 7*s.* 6*d.* to 95*s.* per ton, delivered at works. The iron position still creates considerable difficulty. It is impossible to obtain early deliveries except under contract specifications, though there is some slight evidence that hematite makers are more anxious to secure an outlet for their mid-summer output. Official quotations, as last revised, stand as follow:—Hard basic steel billets, 11*l.*; soft basic steel billets, 10*l.*; West Coast hematites, 6*l.* 15*s.* to 7*l.*; East Coast hematites, 6*l.* 15*s.* to 7*l.*; Lincolnshire foundry, 5*l.* 10*s.* to 6*l.*; Lincolnshire forge, 5*l.* 5*s.* to 5*l.* 10*s.*; Derbyshire foundry, 5*l.* 10*s.*; Derbyshire forge, 5*l.* 5*s.*; bars, 12*l.* 10*s.* to 13*l.*; sheets, 15*l.* to 16*l.* Activity in the engineering section is most noticeable in wagon and locomotive building. More men are being taken on, and rolling mills are being pressed for deliveries. Some of the Colonies are in the market for a fair weight of axles and tyres. It is anticipated that the forward movement will gain strength, as it becomes evident that prices of finished goods, including rolling stock and railway materials, are not likely to recede from the current level. The tool trades present few features of note, except that makers of files and edge tools generally are sending out representatives to cultivate the cheaper markets overseas.

South Yorkshire Coal Trade.—Though there is not the same pressure for deliveries as was the case a month ago, official quotations for all grades are fully maintained, with the exception of blast furnace coke, which, being more abundant, is quoted at 50*s.* to 55*s.* for shipment and 32*s.* 6*d.* for home consumption. The shortage of coking slacks places sellers in a strong position, but the supply of industrial smalls is more than ample to meet the demand. Gas fuel on the week is disappointing. Collieries are not inclined to accept lower rates for best steams, having big order books for export. House coal is easier with the advent of warmer weather. Quotations:—Best branch handpicked, 32*s.* 6*d.* to 34*s.* 6*d.*; Barnsley best Silkstone, 28*s.* to 30*s.*; Derbyshire best brights, 25*s.* 6*d.* to 27*s.* 6*d.*; Derbyshire best house, 23*s.* to 24*s.* 6*d.*; Derbyshire best large nuts, 20*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 21*s.*; Yorkshire hards, 22*s.* to 24*s.*; Derbyshire hards, 21*s.* to 24*s.*; rough slacks, 12*s.* to 14*s.*; nutty slacks, 10*s.* 6*d.* to 12*s.* 6*d.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The Cleveland pig-iron market presents few new features. Business is extremely quiet, and whilst there are practically no stocks, output is now about meeting current needs, and makers are becoming anxious to arrange contracts to take the place of those approaching completion. Customers are holding off in the hope of another cut in quotations, notwithstanding the emphatic protest of producers that conditions will not admit of further price concessions. Certainly costs of output keep very high, and there seems little likelihood of them being at all materially reduced in the near future. Values are, however, if anything, weaker. Market quotations stand at 130*s.* for No. 1 quality, 125*s.* for No. 3 g.m.b., 120*s.* to 122*s.* 6*d.* for No. 4 foundry, and 117*s.* 6*d.* for No. 4 forge.

Hematite.—Owing to its comparative cheapness East Coast hematite is being inquired for by firms that usually consume Cleveland pig-iron, so that there is some promise of a little expansion of demand, but the output has just been increased by the relighting of two furnaces at the Thornaby Ironworks of Messrs. Whitwell and Co., Limited. Hematite mixed Nos. are not more than 122*s.* 6*d.*, and No. 1 is at a premium of a shilling.

Foreign Ore.—There is no improvement of the foreign ore position. Offers to sell best rubio at 24*s.* 6*d.* c.i.f. Tees fail to tempt consumers, all of whom are not only carrying considerable stocks, but have still very substantial supplies to come forward in fulfilment of contracts made.

Blast-Furnace Coke.—Scarcity of Durham blast-furnace coke continues acute, but sellers are still obliging local regular customers by renewing contracts at round about 44*s.* delivered.

Manufactured Iron and Steel.—Little new is ascertainable concerning finished iron and steel, but it is gratifying to hear of rather better inquiry from the East. Common iron bars are 12*l.*; iron rivets, 14*l.*; parallel packing, 8*l.* 10*s.*; tapered packing, 11*l.* 10*s.*; steel billets, 10*l.* to 10*l.* 15*s.*, according to quality; steel boiler plates, 14*l.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; heavy steel rails, 10*l.* 10*s.*; fish plates, 14*l.* 10*s.*; and galvanised corrugated sheets, 19*l.* 10*s.*

Imports of Iron and Steel.—Returns issued by the Tees Conservancy Commission this week give the imports of

iron and steel to the Tees from Holland, Belgium, France, Norway, Sweden, Germany and coastwise for the six months ending April 30 last, as compared with the same time last year, and the corresponding pre-war period of 1913–14. Pig-iron imported during the months just ended amounted to 4,125 tons, as compared with 30,160 tons for the same time a year ago, and 106 tons in the 1913–14 period; crude sheets, bars, billets, blooms and slabs unloaded to April last reached 37,365 tons, as compared with 27,822 tons for the same time a year ago, and 24,134 tons in the 1913–14 period; and plates, bars, angles, rails, sheets and joists brought to the Tees in the past six months are returned at 6,849 tons, as compared with 2,869 tons for the same time a year ago, and 13,460 tons in the 1913–14 period.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little change in the Scottish steel trade over the week with regard to conditions at the works, but new business is not coming in very freely. Buyers are again holding aloof from the market, and there is some reason in this, as the outlook in the shipbuilding industry is meantime so uncertain. Inquiries for the home market are poor, but on export account they are inclined to get better. The work on hand is keeping things moving just now and will do so for some time yet, but the future is causing some concern, and a settlement of the industrial and political troubles both at home and abroad is anxiously awaited for the improvement of trade. Sectional material continues fairly active, and a good turnover is general. The black sheet trade is quiet for home business, and while there is a moderate amount doing on export account there is nevertheless a dullness over the industry. Prices are steady and are nominally without change, as follows:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—Like its allied industries the bar iron trade of the West of Scotland is not very brisk at the moment, and producers are not booking much in the way of fresh business. The current output is leaving order books fairly bare and prospects are none too bright. The steel re-rolling departments are still quite active as a large volume of business was fixed up during the past few months. Prices continue firm, with "Crown" bars at 12*l.* 10*s.* per ton, delivered Glasgow.

Scottish Pig-Iron Trade.—In the Scottish pig-iron trade the conditions are not quite so good as during recent weeks, as buyers are not very prominent, preferring to hold off until the general trade position is more stable. Orders on hand are accounting for the present output, but little is being booked to fill up the gap made by to-day's deliveries. Inquiries are not very satisfactory either on home or export account. Prices have an easier tendency and are round the following:—Hematite, 6*l.* 7*s.* 6*d.* per ton, delivered at the steel works; foundry iron, No. 1, 6*l.* 2*s.* 6*d.* per ton, and No. 3, 5*l.* 17*s.* 6*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, May 5, were rather poor and not up to preceding weeks. The total amounted to 862 tons, of which 762 tons went foreign and 100 tons coastwise. The totals for the corresponding week of last year were 479 tons foreign and 103 tons coastwise, making the gross shipment 582 tons.

THE INSTITUTE OF METALS.—The Journal of the Institute of Metals, vol. xxviii, contains the twelfth May lecture, on "The Relation of the Elements," by Sir Ernest Rutherford, together with the papers that were read at the Swansea meeting last September, and the discussion thereon. Together with the index, the book has 1,010 pages, several hundred pages more than any previous volume. Judging from the activity of the last spring meeting, held on March 7 and 8, the volume now in course of production may be bulkier still, a proof of the increasing activities and usefulness of the Institute. The journals can be obtained from the Institute, or from any bookseller. The price of vol. xxviii, is 31*s.* 6*d.* net.

THE SHAWINIGAN WATER AND POWER COMPANY.—A contract for the hydraulic machinery and equipment for the new St. Maurice power project of the Shawinigan Water and Power Company, Montreal, has just been awarded to the Dominion Engineering Works, Limited, Montreal, licencees of the William Cramp and Sons' Ship and Engine Building Company. There are to be four 30,000 h.p. propeller-type turbines, to be built according to the latest designs developed by the I. P. Morris Department of the Cramp Company. They will, consequently, be the largest turbines of this type in the world, exceeding in unit capacity those recently completed by the Dominion Engineering Works for the Manitoba Power Company, Winnipeg. The contract, for 120,000 h.p., is also one of the largest orders for power machinery ever placed at one time in Canada, and the new station, when completed, will give the Shawinigan Company, from its three plants on the St. Maurice River, a total of over half a million horse-power for distribution over its high-tension lines to Montreal and vicinity. The turbines are to operate under a normal head of 60 ft., and to run at a speed of 130 r.p.m. Among the most interesting of their new features will be the Moody diagonal-flow, propeller-type runner, and the Moody spreading draft tubes. The electrical equipment will be furnished by Westinghouse.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—For the greater part of the past week the coal market was in a depressed condition. Buyers were holding off and middlemen were "cutting" colliery prices to the extent of 3*s.* a ton. On Monday most of the collieries in the coalfield were idle, and the loss of a day's output combined with the fact that there will be another three day's stoppage at Whitsun caused colliery salesmen to stiffen their prices. In this policy they were helped by the fact that buyers in a number of cases put off placing business in the hope of securing more favourable terms, and yesterday and to-day there was an improved demand for cargoes and bunkers for boats already in dock, which shippers are desirous of getting away before the holidays. Buyers, too, have become chary of dealing through middlemen, as they have experienced difficulty in securing supplies owing to the inability of collieries to stem. Best Admiralty large coals are now firm at 40*s.*, with seconds from 39*s.* to 40*s.* Best dry large is round 37*s.* 6*d.* and ordinaries 35*s.*, while the leading descriptions of Monmouthshire large are firm at 37*s.* 6*d.*, with ordinaries 2*s.* 6*d.* less. In regard to smalls the best steams are available at 30*s.*, with seconds round 29*s.* and drys from 17*s.* 6*d.* to 24*s.*, according to quality. Exports of coal last week totalled 624,170 tons, or 60,000 tons less than in the previous week. Shipments to France amounted to 204,240 tons, Italy 170,210 tons, South America 60,930 tons, Spain 50,570 tons, Portugal 19,540 tons, Greece 2,880 tons, British coaling depots 23,280 tons, United States 5,200 tons, Canada 629 tons, Belgium 19,190 tons, Holland 9,860 tons, Germany 22,030 tons, and other countries 25,590 tons.

Timber from Newfoundland.—A visit was made to the United States and Canada last year by Mr. H. Franklin Thomas, of Messrs. H. F. Thomas and Co. (Cardiff), Limited, and Mr. J. O. Williams, of Messrs. J. O. Williams and Co., Limited, the result of which has been the acquisition of an area over 100 sq. miles, in the neighbourhood of Indian Bay, Newfoundland, containing a considerable quantity of black spruce. It is the aim of the promoters of the enterprise, who have formed companies in Newfoundland and at Garston, near Liverpool to supply timber to the whole of the United Kingdom collieries. Already exhaustive tests have been made of the timber, which it is stated compares favourably with French and Baltic wood, which at present is so extensively used in coal-mining.

Iron and Steel.—Exports of tin plates and terne plates from South Wales last week amounted to 9,929 tons, compared with 9,725 tons in the preceding week; black plates and sheets to 5,399 tons, against 3,171 tons; galvanised sheets to 1,632 tons, against 3,171 tons; and other iron and steel goods to 1,492 tons, against 3,004 tons.

PERSONAL.—Messrs. Holden and Brooke, Limited, of Manchester, inform us that their agency for the Birmingham District is now in the hands of Messrs. Green and Jackson, Grenville Buildings, 12, Cherry-street, Birmingham.

THE SOCIETY OF CHEMICAL INDUSTRY.—We are informed by this society that the offices of the Institution of Chemical Engineers has been removed from "166, Piccadilly" to "Abbey House (rooms 306 and 307), Victoria-street, Westminster," and the address of the Chemical Engineering Group, from "24, Buckingham-street, Adelphi," to "Abbey House (room 308), Victoria-street, Westminster."

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—An Eastern District meeting is announced to be held at Peterborough, on Saturday, the 19th inst., when a paper is to be read on "Municipal Work in Peterborough," and visits paid to places of interest. A meeting is also to be held, on Saturday, the 26th inst., at Southend-on-Sea, when there are to be a short discussion on papers and visits to places of interest in the vicinity. Applications should be sent to Mr. W. H. Eley, Hon. District Secretary, Council Offices, Newmarket.

STEEL PRODUCTION IN THE UNITED STATES.—Half a century ago, says *The Iron Age*, New York, the annual production of steel in the United States was less than the average daily production during March of this year. Figures for the total tonnage of steel ingots in 1872 placed it at 142,954 gross tons. The production of ingots alone in March, 1923, accounted for 146,500 gross tons a day, if it be assumed that the 30 companies reporting to the American Iron and Steel Institute produced 86 per cent. of the total. Adding 5,000 tons as an estimate for castings, the total is 151,500 tons per day for March. This is 6 per cent. more than the entire year's production of 1872.

INDUSTRIAL FATIGUE RESEARCH BOARD PUBLICATIONS.—The Industrial Fatigue Research Board has issued a *catalogue raisonné* of its publications classified under subjects, including a general series, and collections relating respectively to the metal, textile, boot and shoe, pottery and laundry industries, together with a short list of other publications that have resulted from the Board's work. Copies of this catalogue can be obtained without charge on application to H.M. Stationery Office, Kingsway, and copies of reports already published on forwarding the necessary remittance. Arrangements have also been made that all future reports, which are expected to average about six a year, will be sent on publication to any address against a deposit of 5*s.*

NOTICES OF MEETINGS.

THE INSTITUTION OF AERONAUTICAL ENGINEERS.—Friday, May 11, at 6.30 p.m., at the Engineers' Club, Coventry-street, W. 1. Lecture on "Low-Power Flying," by Major M. E. A. Wright, A.F.C.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 11, at 7.30 p.m., at 39, Victoria-street. Ordinary Meeting: Durham Bursar's Lecture, "The Theory of Resistance to the Flow of Gases and Fluids in Pipes," by Mr. W. F. C. Cooper, B.Sc. (Member).

THE INSTITUTION OF ENGINEERING INSPECTION.—Friday, May 11, at 7.30 p.m., at the Royal Society of Arts, John-street, Adelphi. Paper by Mr. H. J. Davey, M.B.E., entitled "Some Notes on 'Ciment Fondu,' with results of Chemical Analyses, by Mr. H. F. Knight, F.I.C."

THE ROYAL SOCIETY OF ARTS.—Monday, May 14, at 8 p.m.: Howard Lecture, "The Development of the Steam Turbine," by Mr. Stanley S. Cook, B.A.(Cantab.), M.I.N.A., M.I.M. (Parsons Marine Steam Turbine Company). (Lecture III.) Wednesday, May 16, at 8 p.m.: Ordinary Meeting, "Industrial Lighting and the Prevention of Accidents," by Mr. Leon Gaster, F.J.I., Editor of *The Illuminating Engineer*. Sir Malcolm Delevingne, K.C.B., Assistant Under-Secretary of State, Home Office, will preside.

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, May 16, at 12 noon, in the Physical Chemistry Theatre, University College, Gower-street, W.C. 1. General Meeting. Papers to be read and discussed: "On the Refractive Index Changes in Optical Glass occasioned by Chilling and Tempering," by Mr. F. Twyman, F.Inst.P., and Mr. F. Simeon, B.Sc., F.Inst.P.; "Notes on Burettes," by Mr. Verney Stott, B.A., F.Inst.P. Wednesday afternoon, at 2.45 p.m.: "A New Method of Glass Melting," by Mr. A. Ferguson; "The Drying Out and Warming Up of Tank Furnaces," by Mr. C. Saxton; "Notes on the Design of Pot Arches," by Mr. T. Teisen, B.Sc. Wednesday evening, at 7 p.m. for 7.15: Annual Dinner at the Hotel Cecil, Strand, W.C. 2. Thursday, May 17: Visit to works.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May 16, at 5 p.m., at 49, Cromwell-road, South Kensington. The following papers will be read: (1) "The Fluctuations of Annual Rainfall in the British Isles Considered Cartographically," by Mr. M. de Carle S. Salter, Superintendent, British Rainfall Organisation, and Mr. J. Glasspoole, M.Sc., A.I.C.; (2) (*a*) "An Improved Actinograph," (*b*) "Note on the Influence of a Glass Shade," by Mr. A. W. Clayden, M.A.; (3) "Notes on the 'Sumatras' of the Malacca Straits," by Captain E. E. Benest.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 18, at 9 p.m., a discourse will be delivered by Mr. William Morris Mordey, Past Pres. I.E.E., M.Inst.C.E., M.R.I. The subject is "Recent Studies in Alternating Magnetism" (with experiments).

THE PHYSICAL CHEMISTRY OF THE PHOTOGRAPHIC PROCESS.—The Faraday Society will hold a general discussion on this subject on Monday, the 28th inst., in the Hall of the Institution of Electrical Engineers, Victoria Embankment, W.C. 2. Professor W. D. Bancroft, of Cornell University, will open the proceedings at 3 p.m., with an introductory address on "The Theory of Photography." This will be followed by detailed consideration of the subject. Members of the Chemical Society are invited to attend this meeting. Full particulars may be obtained from the Secretary of the Faraday Society, 10, Essex-street, London, W.C. 2.

THE INTERNATIONAL AIR CONGRESS.—We are informed that the arrangements for the International Air Congress which will be held in the building of the Institution of Civil Engineers, St. George-street, S.W. 1, from June 25 to 30 next, are now practically completed. Altogether about 36 papers dealing with all branches of aeronautical development and of a thoroughly international character will be read, and visits will be paid to various Government experimental and research establishments, as well as to Royal Air Force stations and the works of private firms. Applications for membership, which will be accepted up to June 9, should be addressed to the Secretary, at 7, Albemarle-street, London, W. 1.

SCHOLARSHIPS IN ENGINEERING.—The Society of Merchant Venturers offers for competition 15 scholarships tenable in the day classes of the Faculty of Engineering of the University of Bristol, which is provided and maintained in the Merchant Venturers' Technical College. Candidates must be not less than 17 years of age and must have matriculated. The scholarships provide free tuition; one of the scholarships is open to pupils in any secondary school receiving grants from the Board of Education; three are restricted to pupils of secondary schools situated in the counties of Gloucestershire, Somerset and Wiltshire (one to each county); ten are restricted to the sons of officers in His Majesty's service who were killed in the Great War, and whose mothers or guardians are, in the opinion of the treasurer, in needy circumstances; one is restricted to a son of a citizen of Bethune who has passed either the B.L. or the B.Sc. examination. A war memorial scholarship is also offered with a preference to a candidate who needs pecuniary help who is the son of a former student who lost his life while serving with H.M. Forces during the Great War. Further particulars can be obtained from the registrar of the College.

GENERATORS FOR THE BRUSH-LJUNGSTRÖM 5,000-KILOWATT UNIT.

CONSTRUCTED BY THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, ENGINEERS, LOUGHBOROUGH.

(*For Description, see Page* 577.)

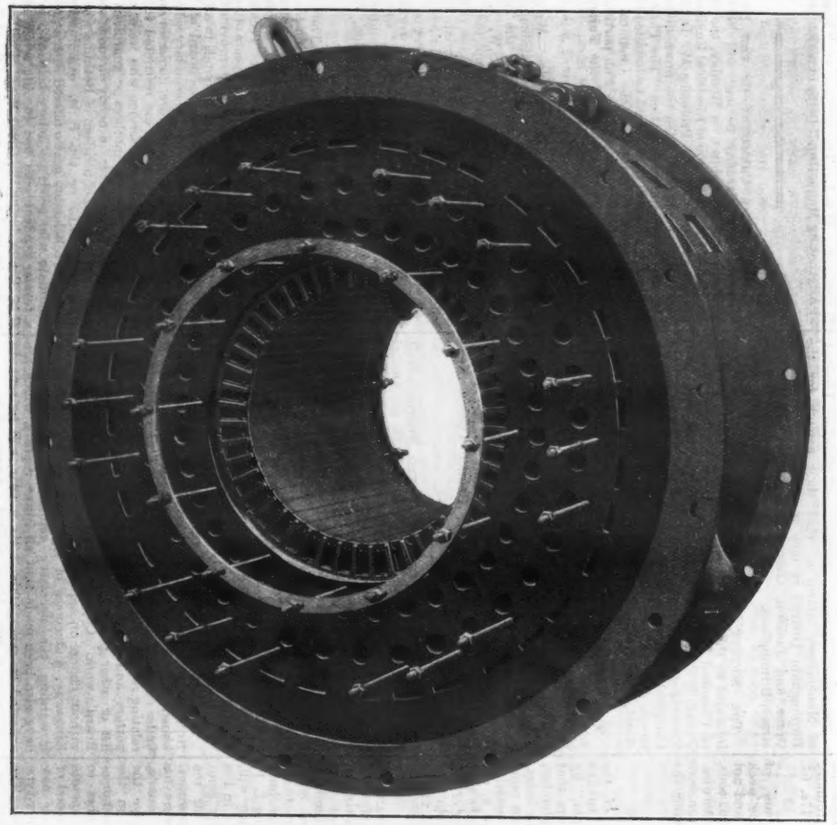


FIG. 57. STATOR OF ALTERNATOR READY TO RECEIVE WINDINGS.

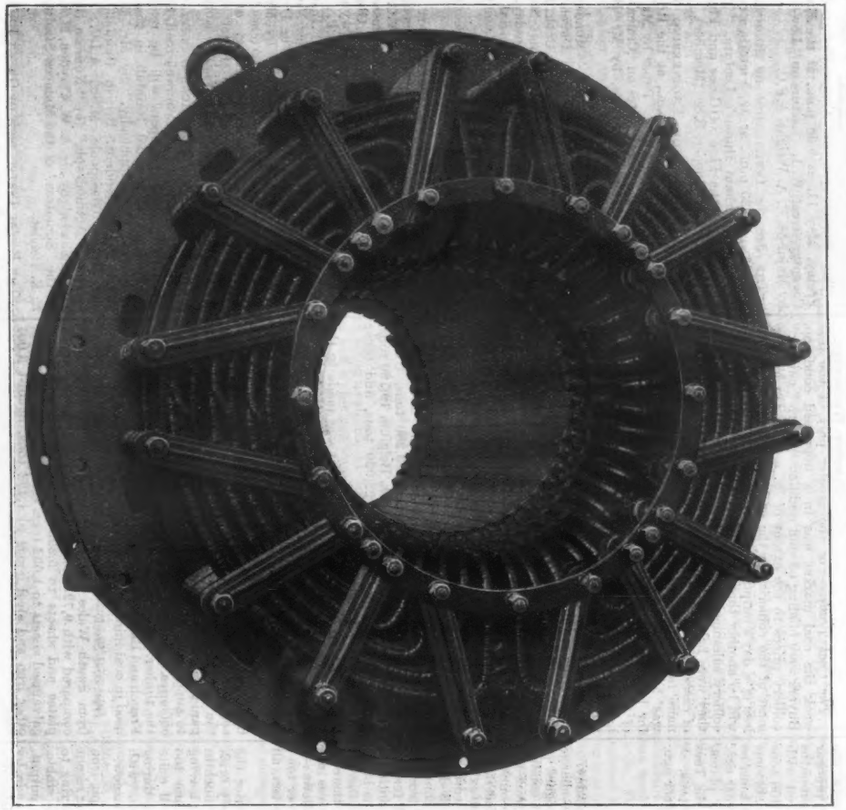


FIG. 58. COMPLETE STATOR OF ALTERNATOR.

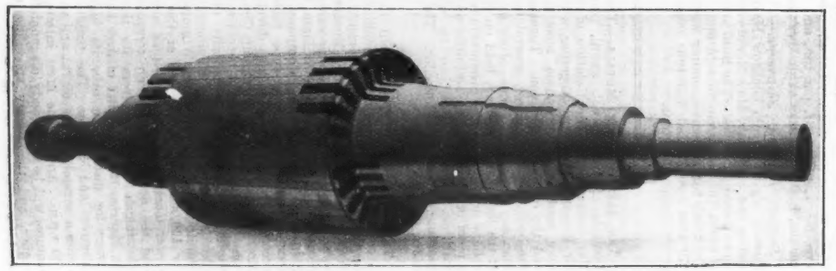


FIG. 59. ALTERNATOR ROTOR, MILLED FROM THE SOLID.

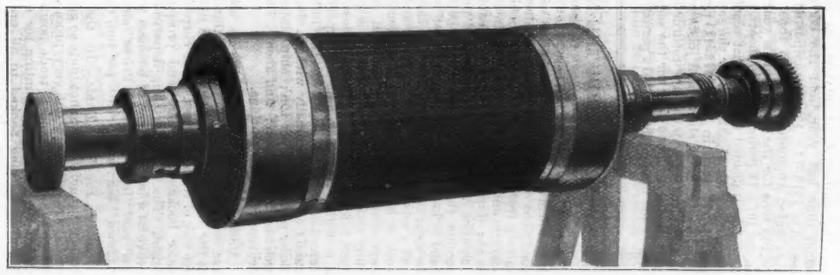


FIG. 60. ROTOR READY FOR MOUNTING IN PLACE.

Fig. 59. Alternator Rotor, Milled from the Solid.

Fig. 60. Rotor Ready for Mounting in Place.

DETAILS OF 5,000-KILOWATT BRUSH-LJ

CONSTRUCTED BY THE BRUSH ELECTRICAL ENGINEERING COMP

(For Description see Page

Fig. 18.

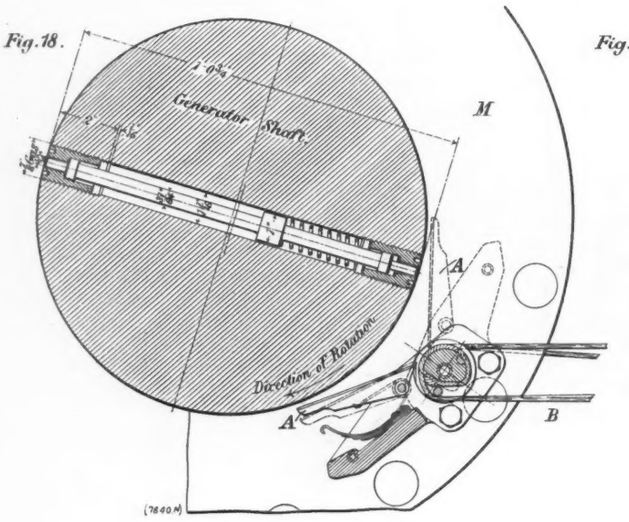


Fig. 19.

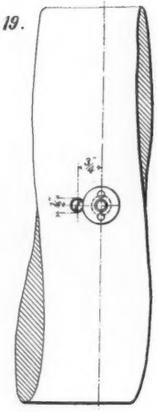


Fig. 20.

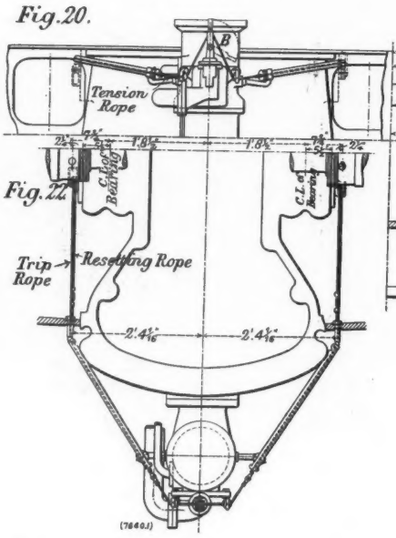


Fig. 21.

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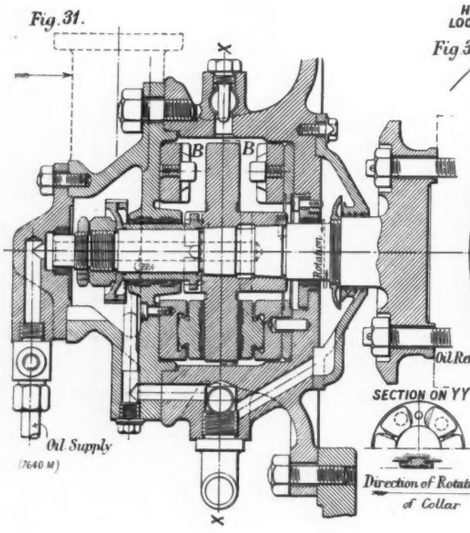
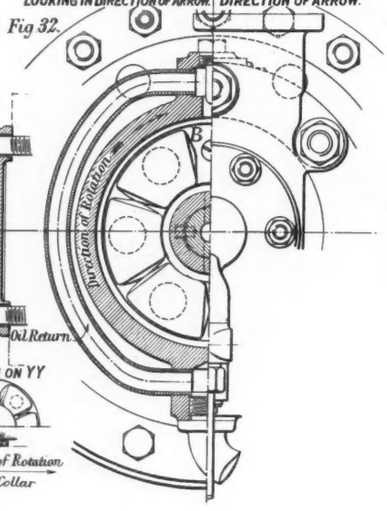


HALF SECTION THRO' XX. LOOKING IN DIRECTION OF ARROW. HALF VIEW LOOKING IN DIRECTION OF ARROW.

Fig. 32.



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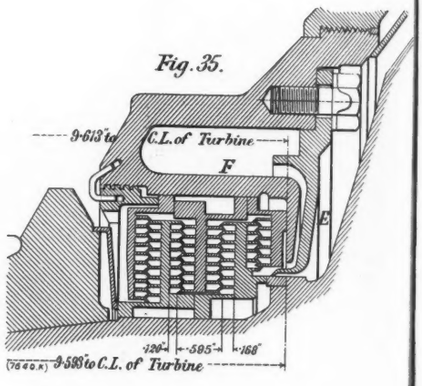


Fig. 36. SECTIONAL ELEVATION.

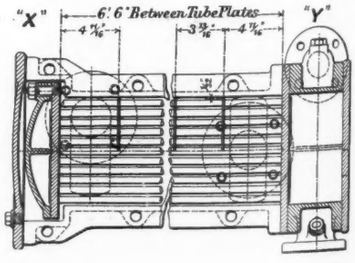


Fig. 34.

Fig. 33.

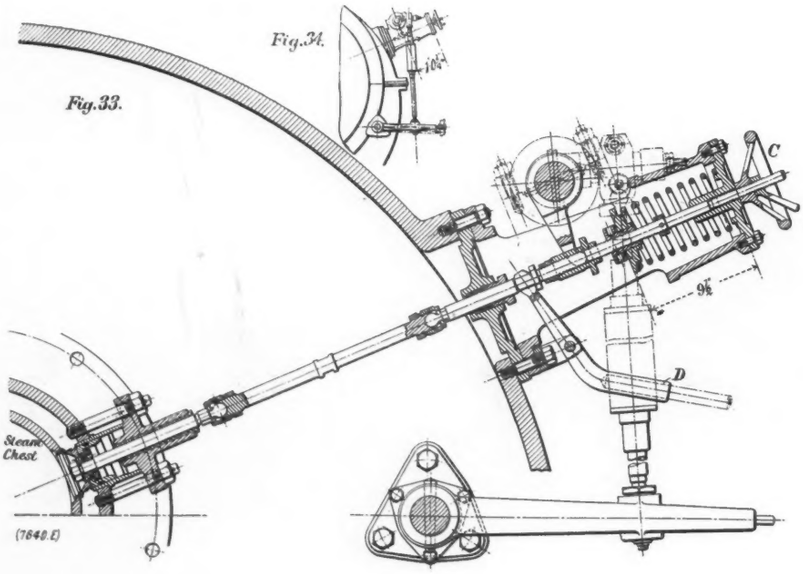
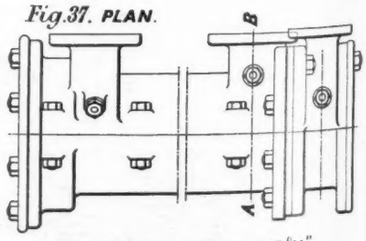


Fig. 37. PLAN.



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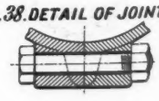

BRUSH-LJUNGSTRÖM STEAM TURBINE.

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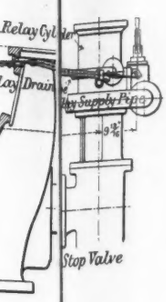


Fig. 23. STOP VALVE

Fig. 24. SECTION A.B.

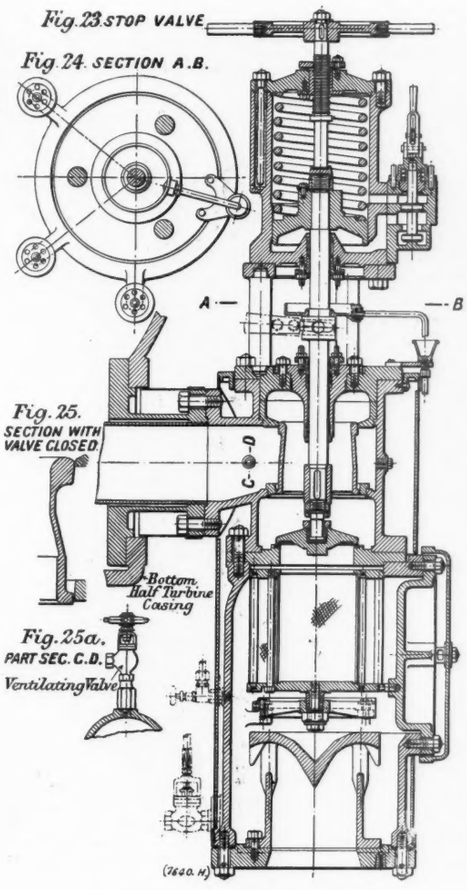
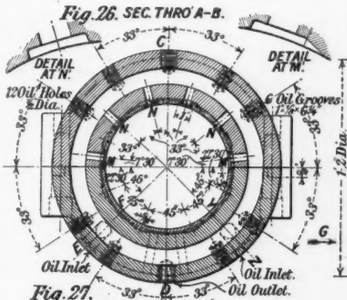


Fig. 25. SECTION WITH VALVE CLOSED.

Fig. 25a. PART SEC. C.D. Ventilating Valve

Fig. 26. SEC. THRO' A-B.



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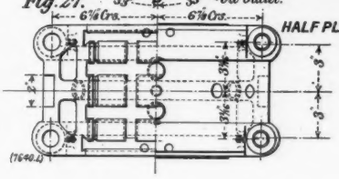

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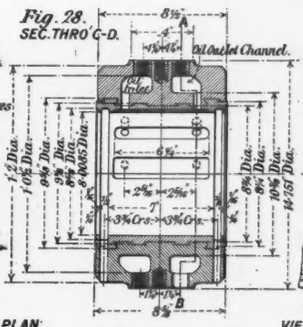
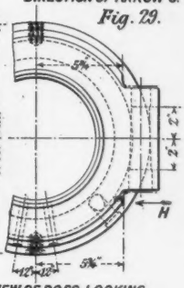


END VIEW LOOKING IN DIRECTION OF ARROW 'G'.

Fig. 29.



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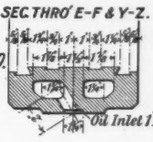

VIEW OF BOSS LOOKING IN DIRECTION OF ARROW 'H'.

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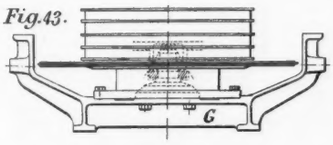

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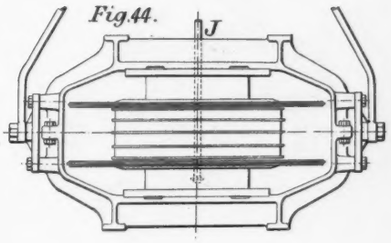

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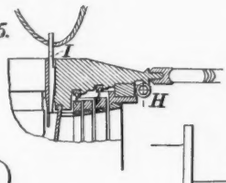

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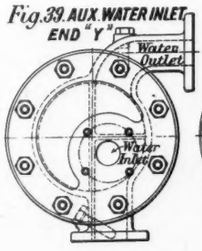

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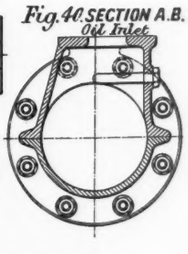

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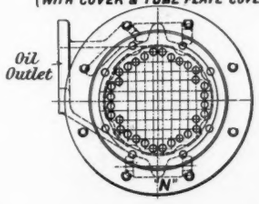

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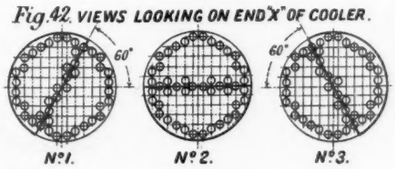
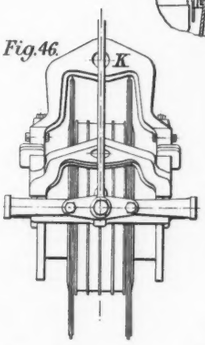


SETTING OF BAFFLES.

Fig. 46.



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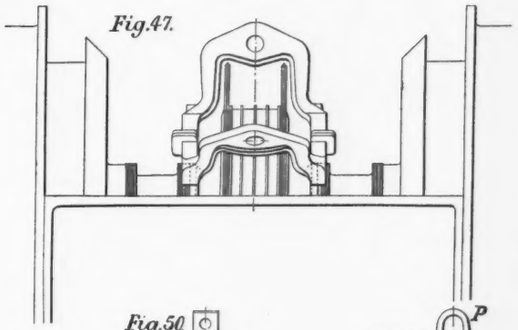

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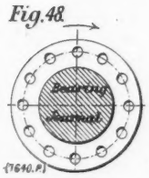

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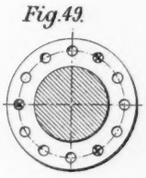
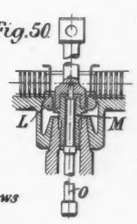


⊗ Forcing Screws

Fig. 50.



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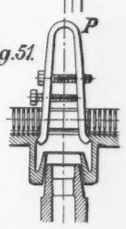

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Two-Page Plate.—DETAILS OF 5,000-KILOWATT BRUSH LJUNGSTRÖM STEAM TURBINE.

ENGINEERING.

FRIDAY, MAY 11, 1923.

RAILWAY ELECTRIFICATION FINANCE.

THE general case for railway electrification has been made time and again, and matters are carried little further when we are told that, for suburban working, terminal and line capacity are increased ; while for main line working a more uniform running speed is possible and the locomotive maintenance requirements are less, and so on. In these conditions it was therefore a pleasure to find that in the paper which Sir Philip Dawson presented to the Institute of Transport on Monday last these general facts were assumed, and attention was directed to the single question of the financial benefit likely to accrue from conversion. The paper was based on a series of investigations undertaken on the London, Brighton and South Coast Railway, and begun in 1919 with a view to the definite consideration of the electrification of the non-converted part of the suburban system and the main line services to Brighton, Eastbourne and Worthing. It is clear that valuable data bearing on this subject should be available on the Brighton system, since in common with the Liverpool and Southport line and the suburban services around Newcastle it represents the conversion of a normal steam line and has been in operation over a considerable number of years. The electrified lines of the London Underground Railways form a special case from which general arguments can hardly legitimately be drawn.

It is common knowledge that suburban railway electrification in this country has usually led to important increases in traffic, but this mere fact in itself is not evidence that such electrification is likely to be a financial success. Quite apart from the new capital charges which electrification represents and the question of the relative operating costs of steam and electric services, comparison of the two cases is rendered difficult by the contrast which usually exists between the facilities offered by the electrical service as compared with the steam service it has superseded. Electrical operation lends itself readily to a frequent and rapid schedule and has usually been associated with a progressive policy, and a true idea of the inherent traffic-making qualities of electrical working will not be obtained if modern facilities of this kind are compared with the conditions still existing on some of our suburban lines on which traffic possibilities are complicated by the running of three classes of coach, and passengers are discouraged by failure to issue third-class season tickets, or the issue of them only under vexatious restrictions and in similar ways. The superiority of electric operation from the point of view of an intensive service needs no argument at the present day, but a correct idea of the traffic-making power of electrical working will not be obtained if it is to be credited with the results which have followed from the abandonment of some of the traffic-repressing archaic notions which still persist in some quarters.

In the course of his analysis Sir Philip Dawson, referring to the comparison of train miles or seat-miles, pointed out that what is required in order effectually to handle any given traffic is to provide seat-miles equivalent to the passenger-miles and at a varying rate per hour corresponding with the demand, and remarked that with steam trains the seat-miles per day may be greater than with electric trains owing to the longer trains hauled by steam during slack hours of traffic. This point has nothing to do with Sir Philip, who was only concerned to analyse matters as he found them, but it illustrates one of the improvements which it is not unusual to attribute to electric operation, but which by no means need be confined to it. Multiple-unit electric working lends itself readily to the division and the running of lighter trains during the slack hours, but procedure of the same kind is not impossible with steam services, and has been carried out in some instances on an extensive scale. No doubt this kind of work requires some consideration and work by the traffic department, but if they are prepared to carry it out in the case of an electric service and not in that of a steam one it is hardly fair to attribute all the saving in the hauling of empty stock to the conversion.

The investigation on which Sir Philips' paper was based was, as we have said, undertaken to determine the financial results likely to follow the completion of the suburban electrification and the conversion of the main line. To obtain accurate figures on which to base a judgment of this kind is a difficult matter as the figures in the railway companies' accounts are totals for the whole railway. The matter was dealt with for the purposes of the investigation by dividing the railway into two areas, the one comprising all the sections over which suburban trains are operated and extending from London Bridge and Victoria to Epsom, Coulsdon and Oxted, and the other comprising the lines from Coulsdon to Worthing, Brighton, Seaford and Eastbourne. To ascertain the proportional effect of electric operation on portions of the railway, and to apportion all charges and train data between the areas and the several classes of service affected, and to relate these to the complete statistics of the railway, is a task of much labour and judgment. The nature of the difficulties involved is illustrated by the fact that to complete the task properly it is necessary to divide the total locomotive expenditure between goods and passenger traffic.

This question of allocating costs has been much discussed in railway circles, but no general agreement on method has ever been come to. Sir Philip had the assistance of the accountant, the locomotive engineer and the superintendent of the line in the work, but no details of the methods employed are given in the paper, so that it would be difficult for any other railway company to know how far it would be justified in going in accepting the results. The Brighton line has, however, a comparatively simple traffic and one may assume that the charges have been allocated with some accuracy. It is stated, however, that the division of locomotive expenditure between goods and passenger services could not be directly obtained, and that it was deduced from the respective costs per train-mile for these services. In the results of the investigation which are given in the paper no capital costs are quoted, so that the results cannot be applied directly to any other railway which might be prepared to accept the traffic results of electrification which are given and apply them to its own case. Such capital costs could, however, be worked out for other lines with

little difficulty. The unknown factor in this matter is not the cost of conversion, but the results, financial and otherwise, that are likely to follow it.

Sir Philip presents his results in a series of 12 diagrams representing the number of passengers travelling, the gross receipts and operating costs, the train-miles run, &c. It is not necessary that we should attempt to analyse all these diagrams, but reference may be made to some of them. The first deals with the passengers travelling, and shows that from the end of 1909, when the first part of the electrical service was inaugurated, the number of passengers travelling by electric train has on the average shown a steady rise to 1920. The number of passengers travelling by steam trains decreased between 1909 and 1917, and then rose until 1920. Since 1920 both types of service have shown a fall, but it is greater in the case of steam trains. It is difficult to see that this diagram in itself illustrates any superior revenue earning power in electric traction. The number of passengers travelling by steam train naturally fell off when part of the field was taken over by the electric services, and the more rapid fall in steam traffic in the lean period since 1920 may surely be explained partly by the fact that the electric lines deal with a suburban traffic which is less likely to be affected than long-distance traffic by the community restricting its expenditure on travel. The train-miles run were fairly regular on the electric lines, but showed considerable variations in the steam services, falling very considerably in the difficult years of the war.

One of the most interesting diagrams in the paper gives the gross and net receipts per mile of single track. This diagram deals with the period from 1913 to 1921, and while all curves show a fall in 1914, the electric receipts, both gross and net, have shown a continuous increase since 1914. In the case of the whole system there is a fall from 1919 to 1921 in net receipts and in gross receipts from 1920–21. The net receipts per mile of electrified track were 2,800*l.* in 1913, 5,000*l.* in 1919 and 6,500*l.* in 1921, while the corresponding figures for the whole line were 1,800*l.*, 3,200*l.* and 2,800*l.* As will be clear, these figures bring out the advantages of electric traction in a very marked way, although the traffic is naturally very much denser on the electrified suburban lines, so that a greater return per mile of track might be expected; this is offset to some extent by the fact that the net receipts per train-mile were from two and a-half to three times greater on the main line steam section than on the electrified lines. It is when the suburban steam lines are compared with the suburban electrified lines, however, that the success which has attended electrification is best brought out. Compared with the figures of 2,800*l.*, 5,000*l.* and 6,500*l.* for the electric service which we have quoted, the corresponding figures for the suburban steam service were 1,200*l.*, 2,100*l.* and 660*l.* A net return per mile in 1921 with the electric service 10 times that obtained with the steam service is a remarkable tribute to the earning power of the newer system. An obvious criticism in connection with these figures is that the railway company would obviously electrify the most promising lines first and that the remaining steam suburban services represent the residue. This idea is, however, countered by Sir Philip Dawson, who says that the electrified zone by no means serves the best areas and that there are quite as good, if not better, areas at present served by steam.

It may frankly be admitted that the paper establishes a strong case for the electrification of the remainder of the suburban lines and by inference for the electrification of similarly situated lines on other railways. The extension of the argument to main lines is, however, another matter, and it can hardly be said that a case has been made out for great trunk line electrifications. The Brighton line itself is, however, a special case. In a sense it is all suburban line, and a morning and evening traffic now exists between London and Brighton which has no parallel in any other part of the country. A somewhat similar type of service, but over a considerably shorter distance exists between Liverpool and Southport, and in that case electrification has very fully justified itself. That equal success would follow the electrification of the Brighton main line seems not improbable, and the results which Sir Philip Dawson has investigated should do much to help forward the carrying out of that interesting and important work.

THE ABOLITION OF EUCLID.

THE newspapers recently announced the death of a gentleman who had formerly occupied the position of mathematical master at one of the leading Midland schools and had written many books dealing with mathematical subjects. One of the notices further remarked he had taken a leading part in the abolition of Euclid as an compulsory subject in the teaching of mathematics. To many who are not directly concerned in educational matters, the step referred to will come as a surprise, but they will find if they take the trouble to inquire, the elements, on which they probably spent many trying hours in their schooldays, are now banished from the curriculum of the majority of schools in the kingdom. The name of the philosopher of Alexandria who, twenty-two centuries ago, elucidated the many problems of geometry will soon be unfamiliar, and the Asses Bridge will have passed into the limbo of forgotten things.

The circumstances in which this abolition was determined upon are not stated, and no information is given as to the substitution of another subject to fill the vacancy. It is to be hoped that before such a drastic step was decided upon, an adequate discussion on the part of those who were most closely concerned was arranged for. It would be interesting to know, for instance, if the opinions of any of the leading engineering authorities were obtained and considered. If this important question were settled by the education authorities alone it is to be regretted, for usually their views are limited, and to many it would appear their principal purpose is to render educational methods as easy and pleasant as possible, without giving full and adequate consideration to the effect which their decisions and methods may have on the future of the students who are concerned.

There is little doubt a great amount of time was devoted to the study of the elements of Euclid, when it still formed a part of the ordinary school course. A proportion of that time could, however, have been economised, if a scholar at the early stages of his acquaintance with the subject had been instructed in the objects of and the methods adopted in the works of the philosopher. The experience of at least one scholar, and it must have been also that of his classmates, was that his teacher was fully satisfied, so long as he could recite without any very serious mistakes the proposition of Euclid which he had been directed to learn, and on the preparation of which he had spent some considerable time. No other test of his knowledge was applied, and his teacher had no suggestions to offer as to any improvement which might be introduced either in the construction or proof. The logical arrangement of the particular proposition which had been learnt was not commented upon, or its proper sequence with the propositions which preceded it pointed out to the scholar. It was not until much time had been spent in this way, learning by heart many of the propositions, that the scholar referred to gradually began to recognise and appreciate the object of the work, and the wonderful arrangement which the philosopher had adopted.

At its lowest value Euclid's Elements were an excellent training for the memory, and if one is to judge from the varied and extensive advertisements which appear in the public press from time to time, such a training is very necessary if any success is to be obtained in life. The continued appearance of such advertisements indicates there is a demand for such a training and that a great number avail themselves of the opportunities so presented. The contents convey the impression that many of those who have attained prominence in public life are not only willing, but anxious, to acknowledge the great benefits they have derived, and that their success is in great measure due to one or other of the systems. It is not stated if, in addition to the improvement within memories which such a training effects, any other useful qualification has been conferred on them. It was, however, the fact that a study and knowledge of Euclid was also a great mental exercise, and the student acquired a faculty for painstaking, orderly, consecutive, clear and logical thinking and reasoning, which was bound to prove of great value to him when he entered into a profession. For such purposes Euclid had no rival, and for that reason it must be almost impossible to find an adequate substitute. At a first glance it might appear that to the majority of scholars Euclid would be of little use in their future careers, for they would have no direct use for his many theorems and problems since their businesses were not concerned with the construction of properties of geometrical figures. This, however, is a very shortsighted view, for there is no business in which clear and logical thinking and reasoning are not of primary importance. It has also been urged that many of Euclid's problems, especially those of the second book, can be more easily proved by other mathematical processes. It has, however, yet to be proved there is any disadvantage in the ability to consider a problem from many different points of view.

It is impossible to judge the effect of the banishment of Euclid from our schools, but it is not difficult to see that with the ever-increasing complexity of the problems with which civilisation is confronted any training which improves or increases the number of clear and logical thinkers ought to be encouraged. It is the fashion for irresponsible orators, dissatisfied with the established systems of government and industry, to suggest various revolutionary schemes by which they may be improved. They enunciate such schemes but the construction, proof and demonstration are carefully avoided. They have not the Euclidean sense and their auditors, with even less, acclaim the new proposals. Possibly this is the result of the abolition of the philosopher from our schools. But passing from the general to the particular, it is the experience of one at least that our young engineers are on the whole less painstaking, less correct and less logical than their predecessors, who had to study and pass examinations in the Elements of Euclid. Possibly there are others with a like experience who can confirm this falling-off in the standards, and who will agree with the writer that it is in great part due to the abolition of Euclid from our schools.

INTERNATIONAL ROAD CONGRESS.

THE Congress which opened on Monday, the 7th inst., at Seville—and which will conclude to-morrow, is the fourth of a series organised by the Permanent International Association of Road Congresses which has its headquarters in Paris. The membership of this association is wide, including not only Government representatives, but delegates of public departments, municipalities, county authorities, chambers of commerce, scientific and technical institutions, transport companies, and many industrial and commercial interests. Hence the gathering at Seville is not confined, as was the Railway Congress at Rome, to those directly associated with the construction and operation of the transport system involved—but includes a representative of users and of manufacturing firms and contractors. The activities of the association are not, of course, confined to the organisation of recurring congress—that which preceded the Seville meeting was in London in 1913—but includes research work on an international scale, tests on actual roads and the preparation and issue of reports on various aspects of the road and road traffic problem—some 60 of which have been laid on the table for the Seville Congress. The countries represented in addition to Spain are Great Britain, United States, Canada, France, Italy, Belgium, Switzerland, the Netherlands, Denmark, Sweden, Bulgaria, Roumania, Czecho Slovakia, Japan and Argentina and other South American Republics. Prominent British delegates who accepted the invitation to be present are Sir Henry Maybury, representing the Roads Department of the Ministry of Transport: Mr. C. H. Bressey, chief engineer to that department; Mr. John Brodie, the city engineer of Liverpool; Mr. A. Dryland, the county engineer of Middlesex; Mr. Arthur Collins, of Norwich; Mr. J. S. Killick, late chief engineer to the Roads Department; Mr. A. E. Brooke; Mr. Rees

Jeffreys; and Mr. Frank Pick, of the London Underground Railways.

For the purposes of discussion the Congress had been divided into two sections—one dealing with road construction and maintenance and the other with traffic. They overlap to some extent, but the first section is obviously of greater interest to engineers, and an account of the proceedings will indicate the advance which has been made in methods of road construction and upkeep during recent years. The period which has elapsed since the London Congress, owing to the transport needs of the war period, has, of course, been one of intense development in mechanically-propelled road traffic, and has raised new and pressing problems in highway construction and maintenance. National and local authorities in all countries have been forced to realise that a large percentage of the world's roads are inadequate for modern traffic requirements, and alarmed at the huge financial outlay involved at a time when there is urgent need of economy in national expenditure, road authorities have turned to the engineer for aid. The result has been that in many countries the ancient art of road building is entering a new phase, and there is good reason for believing that engineering science will meet the demand made upon it. The special subjects which are being discussed in the light of numerous reports at Seville, are the progress made in the mechanical appliances used in the construction and maintenance of roads, the surfacing of roads with concrete, the use of bitumen and asphalt for surfacing and the laying of tramway rails on various kinds of road surface. The road itself claimed first attention, and eight reports on concrete road construction came up before the first sitting of the road section on Tuesday, following the formal opening of the Congress on Monday last.

Concrete Roads.

America is, of course, the country in which the concrete road has found most favour. Their first highway of this type was built in Bellefontaine, Ohio, twenty-eight years ago, and with but small maintenance cost is in fair condition to-day. There are now over 62,000,000 sq. yards of concrete roads in the United States, and an interesting report on the whole subject to which 10 engineers and scientists have contributed was submitted as a starting point for discussion of this subject. As the report reminds us, the concrete pavement has been popular in America because suitable materials are available nearly everywhere, and because no proprietary process or machinery is required to construct this type of road. These facts encouraged independent thought on the part of highway engineers all over the States, and it is asserted that the fundamental principles of concrete roads are now well established and understood. There are, however, wide divergencies in the details of construction, design and materials. Questions as to the amount of water to be used in mixing the grading of the aggregate, the need for very careful preparation of the materials if the exceptional stresses—structural and abrasive—which roads have to sustain can be met, have been answered by costly laboratory investigation. The question of reinforcement is one upon which the views of American engineers are still very divergent, but hopes are entertained that a rational basis for designing and placing reinforcement in roads will soon be established. Several varieties of mixes are being used in different States, but that in which the ratio of cement, fine aggregate and coarse aggregate is 1, 2, 3, has been found to give the best results. The Portland cement should give a tensile strength of 200 lb. or over at seven days, and 300 lb. or over at 28 days. In the case of tests of both sands and cement there is a tendency to substitute compression tests of mortar for tension tests. In the case of coarse aggregate the rule is to determine the percentage of wear in a Deval abrasion machine using 50 pieces of crushed rock weighing 500 grammes and running the machine for 10,000 revolutions at 30 r.p.m.

A special report on reinforced concrete methods of construction suggests, as is indeed obvious, that the use of reinforcement therefore becomes an economical consideration only in those cases where the plain concrete pavement 6 in. thick is not strong enough to carry the traffic, and in such cases its cost must be balanced, for economical design, against the cost of additional depth of concrete which will give the plain concrete pavement the required strength. Reinforcement in America takes two forms; first the use of bars in circumferential and corner reinforcement; and second, reinforcement over the entire area of the pavement. The advocates of circumferential reinforcement, hold that by dividing the concrete slab into comparatively narrow strips no reinforcement is required against longitudinal cracking, and that reinforcement is required only to strengthen edges of slabs where corners may develop due to transverse cracking. In such a style of reinforcement it is the usual practice to use two $\frac{1}{2}$-in. or $\frac{3}{4}$-in. bars about 6 in. and 12 in. from the edges of the pavement and joints respectively, these rods being usually placed at a depth from the surface of one-half the total depth of the pavement.

Those who favour the top reinforcement system are divided between those in favour of light and heavy reinforcement. Light reinforcement advocates, are in favour generally of a mesh placed about 2 in. from the top of the pavement, this mesh being insufficient to give the pavement any particular additional strength, but heavy enough to hold the adjoining sections together if cracking occurs. The amount of steel recommended in such cases is generally about 4 lb. per square yard. The advocates of the heavier type generally favour the use of a heavy mesh or bars amounting to about 10 lb. per square yard, placed about 2 in. below the road surface, their contention being that this amount of steel will serve to hold adjoining sections together if cracking occurs and prevent movement, and at the same time will very materially increase the strength of the pavement in beam action. Advocates of the type which includes both top and bottom reinforcement, generally favour what is commonly known as "bird cage" reinforcement, the "bird cage" being constructed of longitudinal and transverse rods placed about 1 in. from both top and bottom surfaces of the pavement and supported on the sub-grade. The amount of steel in such design is generally about 12 lb. per square yard, and is designed to prevent deterioration after cracking occurs.

In Great Britain the concrete road is only now beginning to find favour; but the report which has been submitted is of interest as embodying the opinion of a number of road engineers. Mr. Arthur Dryland is the author of the report, and he has obtained the co-operation of Mr. F. Wilkinson, Mr. J. Alan Johnson, Mr. Arthur Harrison, who have had experience in the London area, of Mr. David Edwards, city-engineer of Bath; Mr. Andrew Warren, Devon; Mr. J. A. Bean, Northumberland; Mr. S. A. Bennell, Monmouthshire; Mr. L. S. McKenzie, Bristol; and Mr. F. E. Wentworth Sheilds. All these engineers have had experience of concrete roads, and the report summarises their opinions and those of the author. One or two conclusions may be briefly stated. For entirely new roads or for the reconstruction of existing unstable roads the results obtained from concrete are held to justify further trial. Any clean stone resistant to crushing or abrasive stresses may be used as the coarse aggregate if properly graded to reduce large voids. The sand for fine aggregate should preferably be coarse and angular, and must be clean. Good quality cement is essential and should amount in quantity to one-fourth part of the bulk of dry mixed aggregate and sand. The water used must be of the least practicable quantity to allow of proper mixing and surface finishing. On the question of reinforcement the opinion was expressed that its efficacy in eliminating or reducing cracks has not yet been clearly demonstrated where the road bed is of a sound and equal character. English experience has not been favourable to the use of expansion joints which cannot, it is said, be relied upon to eliminate the cracks formed by expansion and contraction through temperature, moisture and subsoil changes. Nor apparently has any case been made out for surface tarring concrete roads.

In Canada there are now approximately 650 miles of concrete roads. The report on this subject made by Mr. Gordon Grant, chief engineer to the Highways Branch of the Department of Railways and Canals, is that concrete roads have not been adversely affected by the extremes of Canadian climate with a temperature range of 120 deg. He believes that the construction of this type of road will exceed all others as soon as cement is down again to pre-war prices.

Continental engineers have experimented with various concrete systems, including rhoubenite and soliditit. In the first named method the inventor has made what is stated to be a successful attempt to obtain impermeability and elasticity by making use of a neutral medium in the form of pulverised sawdust which is capable of spreading itself uniformly through the mass of concrete at the moment of mixing. With the sawdust is incorporated a special tarry mixture, but the exact proportioning and the temperature at mixing of the powder remain the secret of the inventor.

Experience in France with soliditit and rhoubenite has, it is said, been satisfactory. In the case of the former it is employed in either one layer or two-layer applications. In two layer roadways there is a lower layer of concrete of ordinary cement and an upper layer of soliditit which is formed of Portland cement, to which is added a product rich in free and active silica. Trials have been carried out at Lyons, in the Department of the Alpes Maritimes, and in the Department of the Rhone, and although it is too early to express a definite opinion regarding the value of the system it is stated that it gives an even and continuous surface like asphalt or wood, but with a slight roughness so that it affords an excellent foothold for horses. Experiments with rhoubenite have been on a more extended scale. The cost of this last-named system is said to work out at about 37 francs per square meter, not including the preparation of the bed. In comparison with ordinary concrete surfaces it is not believed that the result obtained with rhoubenite are superior.

The reinforced concrete surfacings which have been executed in France are on the Pont-a-Mousson system, which consists in laying on a poor concrete foundation an iron reinforcement embedded in concrete containing a high proportion of Portland cement. The reinforcement is in the form of bars. Numerous applications have been made of a concrete surfacing in which materials forming a superficial tesselated work are set, but the report on the subject reserves opinion as to the more extended use of these processes.

(To be continued.)

THE INNER STRUCTURE OF ALLOYS.

The May lecture of the Institute of Metals was delivered on Wednesday evening, May 2, by Dr. W. Rosenhain, F.R.S., of the National Physical Laboratory. In this lecture some most interesting and highly suggestive views were set forth as to how the atoms were actually arranged in alloys, which, as is well known, are in general of far greater utility in the Arts than pure metals.

In commencing his lecture, Dr. Rosenhain said that previous lecturers had dealt with a large variety of subjects ranging over the whole field of metallurgy and allied branches of science, and these lectures constituted an amazing record of facts which were, however, difficult to classify and might indeed be described as a maze of facts. Was there any key to this maze? Were there any unifying principles or theories? The speaker thought that no hope of such could have been entertained were it not for the fresh insight into the structure of alloys which had been obtained by the X-ray studies such as those described in the May lecture delivered by Professor Bragg in 1916. These studies, in the first place, verified and confirmed certain views which had been arrived at by the cruder methods of the metallurgist, but went further in showing not merely that metals were crystalline structures, but also how the atoms were arranged in these structures, so that now we knew in detail the inner atomic arrangement in the crystals of many pure metals.

Alloys were of more interest to the metallurgist, and these alloys were either solid solutions, intermetallic compounds or aggregates of the two. It was therefore desirable to determine the inner

structures of these solid solutions and intermetallic compounds.

In the case of crystals of a pure metal the atoms were, it was known, arranged at the intersections of a space lattice, which was simply a system of lines running in three directions and crossing one another in a regular manner. The centres of the atoms were located at some or all of these crossings. Such a space lattice is represented in Fig. 1. In this case the lattice is formed by the edges of a series of cubes and the diagonals across the faces of these cubes. The corners of the cubes are occupied by atoms, as also the crossing points of the diagonals. Such crystals are classed as "face-centred cubic." These positions were, however, really average positions about which the atom oscillated when disturbed by heat. This disturbance apart, it would be seen that the atoms were arranged along series of straight lines.

Solid solutions formed crystals which were like those of the pure metal, and this fact pointed to the conclusion that the organisation of the solvent metal must be very similar to what it was in the pure state. Where, then, were the dissolved atoms located? It had been suggested that the two different kinds of atom in a solid solution had each its own space lattice, and that such solid solutions were in fact an intimate mixture of two kinds of crystal built up together and forming accordingly a true system of "mixed crystals." This view, however, had been at once put out of court by the results of X-ray studies. Another suggestion made was that the dissolved atoms were pushed into interstices in the atomic spacing of the lattice of the solvent metal. This, however, would cause an enormous expansion of this lattice and this was not found to occur. A third alternative had accordingly suggested itself to the speaker, and this was that the original lattice was maintained intact, but that at some of its intersections atoms of the metal acting as solvent were replaced by atoms of the metal which was dissolved.

This suggestion could be tested by X-ray studies of solid solutions, by which it was possible to determine a certain lattice coefficient or constant, which was known as the lattice parameter and in the case of Fig. 1 is represented by the edge of one of the cubes there shown. If this parameter were measured and if, also, the number of the "foreign" atoms in the solid solution were known, we could calculate what the density of this solid solution should be, and see how the figure thus obtained agreed with direct measurements.

We had thus a direct means of determining whether the atoms of the dissolved metal fitted into interstices in the crystals of the solvent metal, or whether, as suggested, what really happened was that certain of the atoms of the solvent metal were replaced by the "strangers." Measurements made at the National Physical Laboratory by Messrs. Owen and Preston were quite conclusive in favour of the last-named hypothesis. Operating with the copper-aluminium alloys these workers had found the results represented in Fig. 2, which shows the variation in the lattice parameter as the proportion of aluminium was increased.

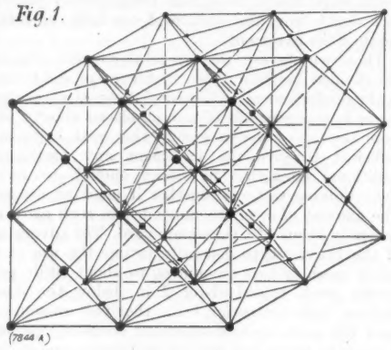
The density determinations made by the same two observers are plotted as circles in Fig. 3, where also Carpenter's measurements of the density of these alloys are plotted as crosses. The inclined straight line about which these lay represents the density as calculated from the lattice parameter and the number of foreign atoms present, whilst the curve shown at the top of the figure represents what the density should have been did the foreign atoms lie in interstices in the lattice of the solvent metal. This latter view, the lecturer added, had been further discredited by measurements made in America.

It was possible, nevertheless, that where the foreign atom was very small, such as that of H, the "interstitial" theory might be valid, but all it was possible to affirm at present was that we did not know whether hydrogen entered into solution in a metal by passing into interstices, or whether it was capable of replacing an atom of the metal in the latter's space lattice. In all ordinary solid solutions, however, this "substitution" theory seemed to be the correct one. It had, moreover, the speaker found, been implicitly assumed in certain work of Tammann's and also to some extent by Bain, but in neither case had actual proof been brought forward.

If this substitution theory were correct, certain conclusions followed immediately.

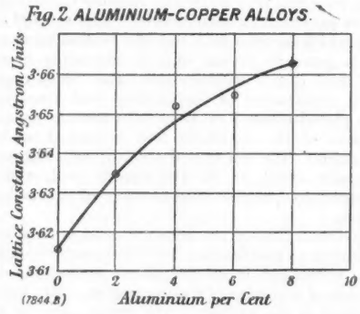
In the first place, the "stranger" atom could not be expected to fill accurately the place of the atom it replaced, and would not exert around it exactly the same forces. Thus suppose the original space lattice was that represented at *a* in Fig. 4, and suppose that one of the atoms of this lattice is replaced by a "stranger." If the attractive forces upon neighbouring atoms which the intruder would normally exert were smaller than those due to an atom of the solvent metal it might be expected that the atoms of the latter would be able to remain further apart. The

Fig. 1.



(7844 A)

Fig. 2. ALUMINIUM-COPPER ALLOYS.



(7844 B)

adjacent atoms of the solvent would therefore be no longer in equilibrium in their old position and would move out, distorting the lattice as indicated at *b*, Fig. 4. It was, however, evident that the distortion could not be purely local, and that the effect would be propagated through many layers producing a slight expansion which gradually died away as the distance from the intruder increased. In all, however, a very large number of atoms would be affected and we thus got in addition to a large local distortion a general expansion of the lattice as a whole.

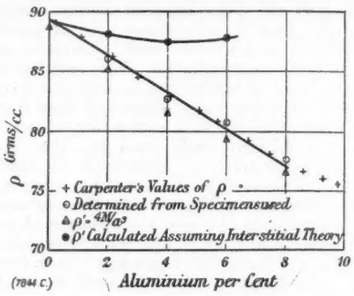
The relative magnitude of the local and of the general distortion would depend upon the nature of the lattice itself. Thus if the lattice of the solvent was comparatively "soft" or flexible the distortion would be mainly local as represented by *b*, Fig. 4. With a stiff lattice on the other hand the local distortion would be less, but the general distortion would be increased; the general character of the disturbance being of the type represented in Fig. 5.

This would be evident if we considered the case of a few steel balls inserted between sheets of rubber and between sheets of steel. In the former case the distortion would be almost wholly local and the average distance between the centres of the sheets of rubber little different than if the balls were absent, whilst in the case of the steel sheets the local distortion would be very small, but the average distance between the sheets would be greatly increased. In the foregoing, Dr. Rosenhain continued, he had assumed that the attractive force exerted by the "stranger" atoms were smaller than those characteristic of the solvent metal. It might, however, be larger, and in that case we should have a contraction instead of an expansion of the parent lattice system.

The space lattice corresponding to any crystalline system could not be stretched beyond a limited amount. Any distension of it meant that energy was stored in the crystalline system. Such a distension might be brought about by heat, by the intrusion of stranger atoms, or by mechanical stress. When the thermal distension exceeded a certain amount the crystals melted, and when excessive distension of the lattice was brought about by the intrustion of solute atoms we got a change of phase, and phase changes of another kind could also be produced by mechanical stresses. These considerations served to explain a good many facts.

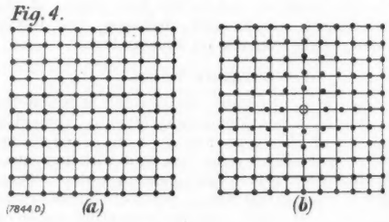
Take for example the case of solid solubility. We could determine by known methods the amount

Fig. 3. ALUMINIUM-COPPER ALLOYS.



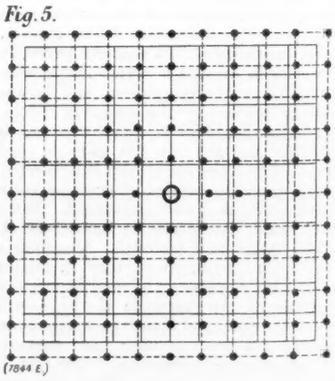
(7844 C)

Fig. 4.



(7844 D)

Fig. 5.



(7844 E)

of energy stored up in solid solutions, but from the considerations set forth above it appeared that the amount of energy which could be stored without a breakdown of the lattice system was limited. Hence there was a limit to the solubility of one metal in another. A large solubility implied it would be seen that each stranger atom introduced into the space lattice of the solvent, produced but little distortion, whilst if each solute atom produced a large distortion in the space lattice into which it intruded, only a very limited range of solid solutions could be formed.

Again, what might be expected to be the effect of the lattice distortion on the mechanical properties of an alloy?

The plastic deformation of a metal took place by a process of slip along some of the crystalline planes. Other things being equal, such sliding would occur most easily when the atoms were uniformly distributed along planes. Any interference with this arrangement would tend to prevent slip, and thus the distortion of a plane lattice system by the

introduction of stranger atoms would increase the resistance to slip, which would thus be a function of the distortion produced. Hence the introduction of a metal with a low solid solubility might be expected to produce a great hardening effect. This inference was in excellent agreement with the known facts as to the hardness of the alloys formed with copper by nickel, manganese, zinc, aluminium and tin. Thus nickel and manganese had a solubility in copper of 100 per cent., zinc could be dissolved up to 36 atomic per cent., aluminium to 14 atomic per cent., and tin to 6·7 atomic per cent. In accord with the view above put forward, the hardness of the alloys found should be greater the lower the solubility, and this was actually the case. In the case of iron the same law held.

It further followed that the property of forming solid solutions should also be a function of the hardness of a metal and of its fusibility. Relatively infusible metals formed long series of solid solutions since their lattice system could absorb a large amount of energy before being broken down. On the other hand tin and lead formed no solid solutions whatever.

Fig. 6.

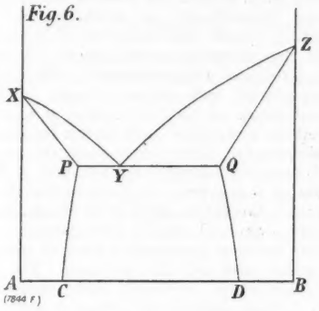
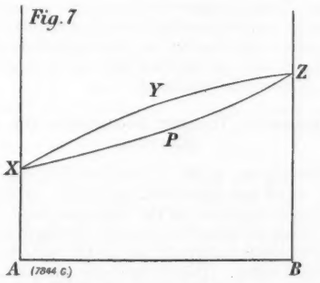


Fig. 7



Crystals of a pure metal melted at one precise temperature. In the case of an alloy, however, the lattice being already distended around the dissolved atoms, melting would begin here long before the rest of the lattice system gave way. We then got the formation of a liquid which contained more of the dissolved atoms than the average of the whole crystal. As the temperature was further raised, the less distorted lattices would melt until finally the whole crystal fused. The temperature required to effect this was, however, lower than in the case of the pure metal because the entire lattice was already distended by the presence of the solute atoms. We thus got a physical explanation of the lowering of the freezing-point and the widening of the freezing range of a pure metal by the addition of an alloy.

Where the solid-solubility of one metal in another was large the liquidus and solidus curves of the equilibrium diagram were near together, as indicated in Fig. 7, a typical instance was provided by the copper-nickel alloys. Where, on the other hand, the solubility was small, the solidus curve dropped away from the liquidus curve very rapidly as shown in Fig. 6, and this occurred with the copper-aluminium alloys, at the aluminium end of the series, where there was a wide gap between the solidus and the liquidus curves.

As already shown the "substitution theory" afforded an explanation of the lowering of the freezing-point of a metal by the addition of an alloy, on the assumption that the replacement of an atom of the solvent metal by an atom of the solute caused a distension of the lattice system. It might, however, happen that this substitution was attended by a contraction of the lattice system in which case the melting-point would be raised instead of lowered, and, moreover, in freezing the first portions of the metal to solidify would be the richest in the solute, whilst that still remaining liquid would contain a smaller proportion of the dissolved atoms. An explanation was thus afforded of the behaviour of the copper nickel alloys. The contraction of the space lattice thus predicted had been proved to exist by Messrs. Owen and Preston at the National Physical Laboratory, while in the analogous case of the Palladium-silver alloys McKeehan had shown that as the proportions of palladium was increased there was a steadily increasing contraction of the corresponding space lattice.

The theory also threw light on the mechanism of solution. In Fig. 8 part of an equilibrium diagram is represented, the constitution of the solidus at any temperature being represented by the lower line and that of the liquidus by the upper curve.

Fig. 8.

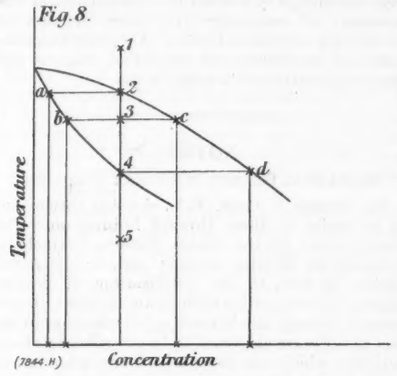
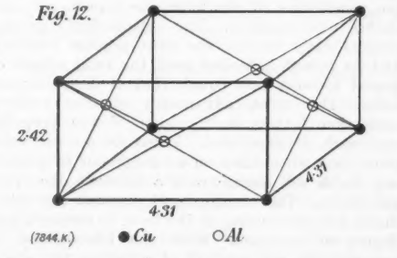


Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.



If the temperature was represented by the line *b c*, then the composition of the solidus was represented by *b* and that of the liquid by *c*. Suppose now that more solute atoms were added to the liquid. Equilibrium would be disturbed and the osmotic pressure would impel solute atoms to penetrate into the solid surface, breaking up the space lattice and freeing solvent atoms, which then found their way into the liquid.

Similarly, when the lattice system was broken down by mechanical strain, the atoms were again freed and formed a new phase which was of the nature of an under-cooled liquid, in which the atoms were less closely packed than in the crystalline phase. It was in this way that the amorphous phase was produced by the deformation of a metal. Heat absorption also increased the energy stored in the lattice system, and if it exceeded a certain limit there was again a change of phase. It seemed, further, that diffusion within crystals ought to be capable of a similar explanation. Here the atoms slipped along the planes of the space lattice. A displacement of this kind could, it was known, be produced by mechanical stress, and the stress required diminished as the temperature rose. In the case of slip produced by mechanical means, the whole structure was involved, but the stress required to bring about slip within a single crystal at a high temperature was not very great, and to produce diffusion it was only necessary for one row of atoms to move at a time. According to the substitution theory the presence of a solute atom produced very high stresses in its neighbourhood, and to account for diffusion all that was necessary was that a slip of one atomic step should occur. If the solute atoms were uniformly distributed, then although the stresses might be high there would, owing to the symmetry of conditions, be little slipping, but if the concentration were not uniform there would be more slipping in the direction of lowest concentration. The resultant diffusion would in fact be brought about by the slipping of rows of atoms in different directions, producing a sort of circulation.

In non-ductile crystals, both of metals and compounds diffusion occurred only near the melting-point, but in ductile metals it occurred more readily.

Another matter on which the theory proposed, seemed to throw light was the electrical conductivity of metals and alloys. Various theories as to the nature of metallic conduction had been put forward, it being assumed that the electrons slid past or through the atoms. The "substitution" theory afforded an explanation of why pure metals were better conductors than alloys, and why this conductivity became higher as the temperature diminished.

As the electrons conveying the current entered at the one end of a metallic wire, an impulse was transmitted through the wire at the speed of light which shot out an equal number of electrons at the other end. We could thus take as a mechanical analogy a series of equal elastic spheres in contact with each other on a smooth table. An impact at the left would be transmitted through the balls and cause the shooting out of the terminal ball at the right, the impulse being transmitted from end to end of the series without loss of energy.

Suppose, however, that as represented in Fig. 10 one of the equal balls was replaced by a large one. Part of the energy entering at the left would now be dissipated in producing a lateral movement at the point where the "stranger" atom had been introduced, and this was analogous to what occurred with alloys. At each point of the crystal lattice distorted by the neighbourhood of a solute atom there was a dissipation of energy. The effects of temperature on conductivity could be accounted for on similar lines. The effect of the thermal agitation was to throw the atoms out of line, as indicated in Fig. 11, and there would again be dissipation of energy.

As the temperature fell the amplitude of the thermal agitation diminished and the atoms got more and more into line. If all were in line, the electrical resistance would vanish, and we got the phenomenon of super-conductivity. That this was met with at a temperature somewhat above the absolute zero was due to the fact that it was not necessary for all the atoms to be in line. If even one straight path was provided the whole of the current would take it.

The theory also indicated why the temperature co-efficient should be smaller for alloys than for pure metals. In the case of alloys the lattice system was already distorted and the thermal effects only increased this distortion. With pure metals, however, the whole of the resistance was due to the thermal agitation.

Coming next to the question of intermetallic compounds the speaker said that these differed from solid solutions in that we had here interlacing lattices and a different type of structure. Very few of these had been examined by the X-ray methods. but Fig. 12 showed the space lattice belonging to the intermetallic compound of copper and aluminium $CuAl_2$, as determined at the National Physical Laboratory by Owen and Preston. It proved to be a flattened-face centred cube, but lacking the central atoms at the two

largest faces. The dimensions in Angström units are shown on the figure. The aluminium atoms occupy the corners, and it may be noted that the distance between the aluminium atoms is much smaller than it is in pure aluminium. Such intermetallic compounds did not enter into solid solutions. Such solid solutions had the space lattice of the solvent metal, and in the case of a solid solution of copper in aluminium we had the copper atoms occupying positions on the aluminium lattice. It would however be impossible to fit into this the molecule $CuAl_2$, although crystals of this compound might separate out from such solutions. Intermetallic compounds were generally non-ductile, and it would seem that ductility depended on the evenness of the atomic spacing. Where, however, there was a great similarity between the atoms of the two metals there might be a certain amount of ductility, as was found to be the case with the copper-zinc compounds. Intermetallic compounds might themselves act as solvents, provided that the two constituents had very similar atoms, but the solvent power of intermetallic compounds was at best very limited.

SURFACE COMBUSTION.

IN a lecture delivered to the Society of Arts, on Wednesday evening last, Professor W. A. Bone, F.R.S., gave an account of the past history and the present position of the system of heating by surface combustion with which his name has long been identified. Experimenting during the years 1902 and 1907, Professor Bone proved (1) that at temperatures below the ignition point all hot surfaces had the power of accelerating gaseous combustion in varying degrees according to their chemical character and physical texture; (2) that whenever a mixture of combustible gas and oxygen (or air) was combining in contact with such a hot surface, the chemical action mainly occurred in, and was usually confined to, the boundary layers between the gaseous and solid phases wherever these might be in contact; (3) that not only did the accelerating influence of a hot surface upon combustion rapidly increase with the temperature, but also that the differences between the powers of various surfaces, which at low temperatures was often considerable, diminished with ascending temperatures until at bright incandescence they practically disappeared; and (4) that all such surface combustion, whether at high or low temperatures, depended upon an absorption of the combustible gas, and probably also of the oxygen, by the surface, whereby it (or they) became "activated" by association with the surface.

In conjunction with Mr. C. D. McCourt certain applications of these discoveries to industrial ends were worked out, and in particular a "radiophragm" was devised which consisted of a porous diaphragm of refractory material through which was forced a homogeneous mixture of gas and air in the right proportions for complete combustion. This mixture was caused to burn at the front face of the diaphragm without flame, and maintained the surface there in a state of red hot incandescence. Several applications of these diaphragms were made, but when Germany wantonly set out on her "short and joyous war" Mr. McCourt joined up and was killed in France in 1916. As a consequence, relatively little further development of the surface combustion principle was possible here till the end of the war, but since then some highly important improvements have, it appears, been effected.

Professor Bone stated that, although very remarkable results were obtained with the McCourt diagrams, there was a limitation to their utility since if their free radiation was by any means so impeded as to allow of too great an accumulation of heat in the incandescent surface layer, which constituted the seat of the intensive catalytic combustion, the latter might in time heat up the next-under granular layer to such a degree as to render it in turn capable of promoting the catalytic combustion. The latter would then leave the surface layer and commence in the one below it. It was thus possible, in circumstances of sufficiently restricted radiation, so to accumulate heat in the incandescent surface layers as to cause the seat of the intensive catalytic combustion originally set up therein gradually to creep backwards from layer to layer in the diaphragm until pre-ignition of the mixture ultimately occurred in the feeding chamber. This drawback has, Professor Bone announced, now been entirely overcome by improvements due to Mr. F. J. Cox, M.I.Mech.E., which have entirely eliminated this risk of backfiring. In one test, made in America, the surface was raised to such a degree of white hot incandescence that the surface layer began to flux, but without any signs of backfiring. Moreover, it is—it was stated—now possible to have two radiophragms operating with their incandescent surfaces opposite each other, at a short distance apart, without either of them backfiring—an arrangement which was formerly impossible. The new radiophragms are supplied by Radiant Heating, Limited, and are already in use for cooking purposes in a number of large London restaurants, and other applications are in the course of development. The great advantage of surface combustion lies in the possibility of consuming very large volumes of gas within a very limited space. Very high temperatures are in consequence attainable, without the use of regenerators or a waste of gas.

NOTES.

MECHANICAL GEARING FOR STEAM TURBINES.

Mr. Stanley S. Cook, B.A., devoted the second of his series of three Howard lectures on "The Development of the Steam Turbine," which he delivered on Monday evening last, at the Royal Society of Arts, to the consideration of gearing working in conjunction with steam turbines. In his opening remarks the lecturer called attention to the fact that the second vessel to be propelled by steam turbines, which was the yacht Charmian, built in 1897, did not have a direct drive to the propellers, but was fitted with gearing. This scheme was later returned to in the quest for efficient speeds of operation for both the turbine and the propeller. The Vespasian was purchased and refitted with steam turbines and gearing in place of the old triple-expansion engines. Tests were run under the two schemes of operation and the advantage of gearing was at once manifest. The experimental results were submitted in a paper by Sir Charles Parsons to the Institution of Naval Architects in 1910. About the same period other investigators were studying the possibilities of the hydraulic transformer and electric transmission. The mechanical gearing method early became the most popular solution, and its growth extended until the total output of geared turbines now equals that of direct-coupled units. The great advantages of the reduced cavitation actions and erosion of the propeller were early demonstrated. When there is one more tooth in a wheel than on its neighbour in a train, any tooth will engage with a different one every revolution. This hunting tooth principle was introduced into the cutting of the teeth to ensure a high degree of accuracy. With the introduction of gearing, the old method of allowing the steam pressure to withstand the thrust action was no longer possible and Michell thrust blocks were introduced. After describing the construction of that type of thrust block Mr. Cook concluded his lecture by referring to the endeavours to obtain a reduction of the kinetic energy losses at the outlet from the low-pressure turbine.

THE JONAS AND EDGAR ALLEN RESEARCH LABORATORIES.

The Jonas and Edgar Allen Research Laboratories, Applied Science Department, University of Sheffield, were opened by Sir Oliver Lodge, on Thursday, the 3rd inst. Sir William Clegg, chairman of the Applied Science Committee, who presided, reviewed the history of the Department, and stated the endowments and donations which had rendered large developments possible, and the number of students who were availing themselves of the facilities offered. Sir Oliver Lodge said that the University of Sheffield having bestowed upon him an honorary degree, he felt it his duty, as a graduate of the University, to accept the Vice-Chancellor's invitation to come to open the laboratories, especially as he felt that it was most important for a University to have laboratories devoted to scientific research, whether for pure or applied purposes. Sir Oliver Lodge then referred to the work carried out by a number of scientists, and mentioned the use of X-rays in connection with the investigation of metallic crystals, the energy locked up in the atom, dust precipitation, and other points of interest. Sir Oliver next expressed his admiration of the new installation at the Sheffield University, and declared the laboratories open. The other speakers included Sir Henry Hadow (Vice-Chancellor), and Mr. Albert Senior. The Jonas Research Laboratory is to be devoted to the investigation of the numerous problems connected with the mechanical testing of materials. Its equipment consists of an 85-ton Armstrong Whitworth machine for tensile, compression, transverse and bending tests, and a 50-ton Armstrong Whitworth machine for tensile tests only. For fatigue tests, a machine designed by Professor B. P. Haigh, and constructed by Messrs. Brunton, Musselburgh, is available, in which alternating, tensile and compressive stresses are applied by electro-magnetic means. A second machine, designed and constructed in the Engineering Department, tests specimens under alternating torsional stress. A third machine is of a modified Wöhler type, and has also been built in the Engineering Department. There are, further, two standard Brinell hardness testing machines, and a Brinell machine of a new type, designed in the Research Laboratory, Woolwich, and built by Messrs. Herbert, Coventry; an Izod impact testing machine, and complete series of instruments used in testing, in conjunction with all the machines. The Edgar Allen Laboratory, designed and organised by Dr. T. F. Wall, provides the means of carrying out research work in magnetism, magnetic properties of materials, and allied subjects, with a very high degree of accuracy, and in a number of important directions. The University of Sheffield is to be congratulated upon this new development.

LJUNGSTRÖM TURBINE LOCOMOTIVE FOR THE ARGENTINE.

Following the action of the Swedish State Railways, which was announced in our issue of March 23 last, the Government of the Argentine Republic has now placed an order for a turbine driven locomotive of the Ljungström type for use on the State Railways in that country. This latter order is a particularly interesting one, for not only is the locomotive of special design, but upon its performance will depend a further order for a large number of engines, the placing of which will be deferred until the first machine has been put to practical tests. The new Argentine locomotive is to be built for the metre-gauge lines and will use oil fuel, in the consumption of which the Ljungström Company have guaranteed to effect a saving of at least 50 per cent. during the cold season and 40 per cent. during the hot season, as compared with ordinary locomotives doing similar work. Furthermore, in view of the difficulties of watering along many of the lines in the country, the condensing properties of the Ljungström locomotive show to great advantage. The total amount of water carried is 5·5 tons in the condenser and 5 tons in the feed-water tank, this being sufficient for a non-stop run of 500 miles, lasting 20 hours. The actual water consumption for such a run with a train of 700 tons behind the tender, will not exceed 4 tons, and the oil fuel carried, namely, 6·5 tons, will suffice for the same journey, the oil being taken to have a calorific value of 18,900 B.Th.U. per pound. The general design of the locomotive will be similar to that very fully illustrated in our issues of July 21, and August 4, 11 and 18 last year, the air-preheating arrangements, the gearing and the arrangement of the condenser elements being, however, modified. The total weight of the machine, in running order, will be 120 tons, and the maximum speed 41 m.p.h. The boiler car is carried on a leading bogie followed by three fixed axles. The condenser car, with the turbine and gearing, is carried on four driving axles, of which one is allowed latent movements, followed by a pony truck. The total wheel-base of the locomotive is 16·6 m., the rigid wheel-base being 3·2 m. The driving wheels are 1,470 mm. diameter. The five axles under the boiler car are loaded with

11·5 tons each, and the driving and trailing truck axles with 12·5 tons each. The horse-power at the rim of the drivers is 1,750 b.h.p. A boiler heating surface of 100 sq. m. is provided, and a superheater surface of 57 sq. m., while the air-preheater, which replaces the more inefficient portion of the ordinary tube surface, has an area of 800 sq. m. The boiler works at a pressure of 300 lb. per square inch. Over a comparatively hilly route similar to that between Stockholm and Upsala, with a 500-ton load behind the tender, the average fuel consumption per 1,000 useful ton-kilometres, will not exceed 8·9 kg. during cool weather and 10·7 kg. during hot weather, while for continuous service on such a route, when the condenser has no time for cooling and the air temperature is at 104 deg. F., the consumption will not exceed 11·6 kg. per 1,000 ton-kilometres of useful load. The machine is being built by Messrs. Nydkvist and Holm of Stockholm, and its performance will be watched with very great interest.

Notable Achievements in Aviation.

On Sunday last, the 6th inst., M. Georges Barbot performed the interesting feat of flying across the Channel in both directions in a small monoplane fitted with a Clerget two-cylinder engine rated at only 15 h.p. M. Barbot crossed from St. Inglevert Aerodrome, near Boulogne, to Lympne Aerodrome, near Folkestone, in 61 minutes and performed the return journey in 44 minutes. The distance between the aerodromes is 31¼ miles measured in a straight line, so that the average speed for the whole flight works out at 36 m.p.h., but as the pilot appears to have gone some distance off a straight course on the outward journey his actual speed must have been higher. The actual speed of the machine, which together with the pilot weighed 552 lb., is said to have been about 70 km. (43½ miles) per hour. The petrol consumption for the two journeys is given as 9 litres (about 2 gallons), from which it would appear that the engine was in use for practically the whole time. It hardly seems correct, therefore, to describe the flights as glides, as has been done in the daily press, although they are certainly remarkable achievements. Their successful accomplishment, we understand, secures for the pilot a prize of 25,000 francs offered by the French newspaper, *Le Matin*. Of even greater importance from the point of view of commercial aerial transport is the flight across the American Continent accomplished last week by Lieutenants J. A. Macready and O. Kelly of the United States Air Service. The pilots left Roosevelt Field, New York, on the 2nd inst., in a T.2. Army Fokker monoplane, and landed less than 27 hours later at San Diego, California, having covered the intervening distance of 2,650 miles without a stop, at an average speed of nearly 100 m.p.h. This is the longest cross-country flight made up to the present. The machine used was fitted with a 400-h.p. Liberty XII engine and it has a wing span of 74 ft. 10 in., a wing area of 958 sq. ft., and an overall length of 49 ft. The total lifting capacity of the machine is 10,850 lb., and at the commencement of the flight referred to the load included 737 United States gallons of petrol, 35 gallons of lubricating oil and the same quantity of water; these together would account for nearly 5,000 lb. It is interesting to note that the same machine and pilots previously attained the world's record for duration and distance, having remained in the air for 36 hours 5 minutes 20 seconds, on April 16–17 last, while flying on a 50-km. course in the neighbourhood of McCook Field, Dayton, Ohio. In this flight, the total distance travelled was 2,541 miles, and the fact that a longer distance was covered in a shorter time in the trans-Continental flight must be accounted for by the prevalence of favourable winds in the latter case. These flights are certainly striking testimonials to the skill and endurance of the pilots and are also evidence of the high degree of reliability now reached in the Liberty engine.

American Steel Rail Production.—We read in *The Iron Age* that the steel rail production in the United States in 1922 was a total of 2,171,776 tons, of which 2,033,000 tons were of open-hearth steel, 22,317 tons were of Bessemer steel and 16,459 tons were re-rolled rails.

THE IRON AND STEEL INSTITUTE.

The fifty-fourth annual general meeting of the Iron and Steel Institute is being held this week in the building of the Institution of Civil Engineers. The meeting commenced yesterday, the chair being taken by the president, Mr. Francis Samuelson, and the proceedings are being continued to-day.

On the members assembling at 10 a.m. yesterday morning, the usual formal business having been disposed of Mr. G. C. Lloyd, the secretary, read the report of the council.

Annual Report of the Council.

The report stated that the total membership of the Institute on December 31, 1922, was 2,237, formed of 2,113 ordinary members, 80 life members, 37 associates, 6 honorary members and 1 patron. Reference was made to the death of several members during the year; these included the honorary member, Dr. Richard Akerman, Bessemer medallist and a member of the Institute for over forty-seven years; the honorary vice-president, Dr. Henry Marion Howe, to whom the Bessemer medal was awarded in 1895; Professor McWilliam, Mr. J. T. Middleton and Professor Hubert. A number of members, upon whom various honours and distinctions had been conferred during the year, were named in the report and received the congratulations of the council.

The statement of accounts for 1922 showed the total income for the year to have been 7,964*l*., exclusive of the Carnegie Scholarship Fund, and the expenditure 7,939*l*. The figures for 1921 were, income 8,349*l*. and expenditure 6,866*l*. The principal item in the expenditure, apart from salaries, was on account of the printing of the Journal. The charges maintained by the printing trades were still exceedingly high, and the expenses involved in the preparation of illustrations were likewise considerably above pre-war rates.

After mentioning the activity of several members as representatives of the Institute in different other Institutions and societies, the report stated that Mr. Francis Samuelson having been elected president of the Institute, Sir Frederick Mills, Bart., had been elected a vice-president to fill the vacancy thus created, and Mr. John Craig was elected a member of council in his place. His honour Judge Elbert H. Gary had been made an hon. vice-president to fill the vacancy occasioned by the death of Professor Howe, and Dr. Carl Benedicks had been added to the list of hon. vice-presidents.

Presentation of the Bessemer Medal.

Mr. Samuelson then proceeded to confer the Bessemer medal upon Dr. William Henry Maw, President of the Institution of Civil Engineers, and in making this presentation said that it was a great pleasure and honour to him to do so, and he was confident that all the members would share his gratification.

Dr. Maw was born at Scarborough on December 6, 1838, and early in 1855, at the age of 17, he became an apprentice at the Eastern Counties Railway Works at Stratford. In 1859, at the age of 21, he became head draughtsman in the locomotive and carriage department, and in this capacity he designed rolling stock for the Great Luxemburg Railway and locomotives for the East Indian Railway, for both of which lines Mr. Robert Sinclair, the engineer-in-chief of the Great Eastern Railway, was consulting engineer. In 1865, whilst still a young man, Dr. Maw left the Great Eastern Railway to join the late Mr. Zerah Colburn in the establishment of Engineering. Dr. Maw had done a great work for the advancement of engineering practice. He not only set in his paper a very high standard as regards the quality of the reproduction of drawings and the precision and completeness of the descriptive matter, he had assisted in every way the developments of new processes and appliances, and he had given useful advice to inventors as to the probable success or otherwise of their inventions.

From 1870 until within a few years ago, Dr. Maw had an independent practice as a consulting engineer, his work being chiefly in connection with engine and boiler construction, the design and arrangement of workshops and other buildings. He was also consulting engineer for several important firms, and one particular phase of his work was the fitting of printing machinery for some of the great daily newspapers in England. Dr. Maw's literary work was well known, and besides many addresses and papers read before various engineering institutions, he was joint author of "The Waterworks of London" and of "Road and River Bridges." Another of his works, "Recent Practice in Marine Engineering," long remained a standard record of developments in this department of science. He was one of the founders of the Civil and Mechanical Engineers Society, and was president from 1863 to 1865. Perhaps the Institution with which Dr. Maw has been most closely connected is the Institution of Mechanical Engineers, of which he became president in 1901. He was a member of various research committees formed by the Institution to carry out work which had been invaluable to the whole profession, and, amongst others, he was a member of the Gas Engine, the Steam Jacket and the Friction of Gears Committees.

He joined the Institution of Civil Engineers in 1896, and in 1903 he delivered the James Forrest lecture. He became president in 1922. His presidential address was characteristic of his original line of thought. He sought to establish the association of developments primarily intended for war purposes with the subsequent manufactures for peace. Dr. Maw was elected a member of the General Committee of the National Physical Laboratory, and was appointed to serve on the Executive Committee in 1905. For the British Engineering Standards Association he has done remarkable work. He was a member of the committee responsible for the foundation of the association, and still continues to be a member or chairman of several of the principal committees. During the war he was a member of the Advisory Panel of the Munitions Inventions Department, and later he was chairman of the committee dealing with machine tools and mechanical transport. The versatility of Dr. Maw's mind and the varied nature of his work is shown by the fact that he served on the committee appointed to consider the simplification of the manufacture of artificial limbs; that he was a member of the Committee of the Western Ophthalmic Hospital for many years; and that he is well-known for his work in astronomy. He is a Fellow and has been president, of the Royal Astronomical Society. During that period he delivered two presidential addresses, one dealing with Professor Campbell's work on the measurement of the motion of stars in the line of sight and the other with "Researches in the Lunar Theory."

He was one of the founders of the British Astronomical Association and for many years served on the Council holding the offices of President and Treasurer. For two years he was a member of the Board of Visitors of the Greenwich Observatory.

Dr. Maw was elected a Fellow of the Royal Geographical Society in 1890, and of the Royal Microscopical Society in 1892. He was also a member of the Board of Studies of the University of London, and in this connection it may be mentioned that in 1909 the University of Glasgow conferred on him the degree of LL.D.

In conclusion, Mr. Samuelson said: "I have now the very greatest pleasure in making the presentation of this medal—the actual medal itself—and it is a very great gratification to me, to the council and to all the members to have the privilege of conferring this medal upon you."

Dr. W. H. Maw acknowledged the presentation by saying that he wished to tender his most hearty thanks to the president and to the council for the honour they had done him. He could assure them that it was one of the most startling surprises that he had ever had when he learnt that the Council of the Institute had decided to award to him the Bessemer medal. He had not at any time regarded himself as at all eligible for the honour. The award was one which he valued greatly, and especially because of the manner in which it connected him with Sir Henry Bessemer. He (Dr. Maw) was first introduced to Sir Henry Bessemer at a London Exhibition in 1862. At that time they were experimenting with steel for locomotive axles and tyres on the Great Eastern Railway, and he spent a good deal of time with Mr. Bessemer, as he

THE WALSCHAERT VALVE GEAR ADAPTED TO INSIDE CYLINDER LOCOMOTIVES.

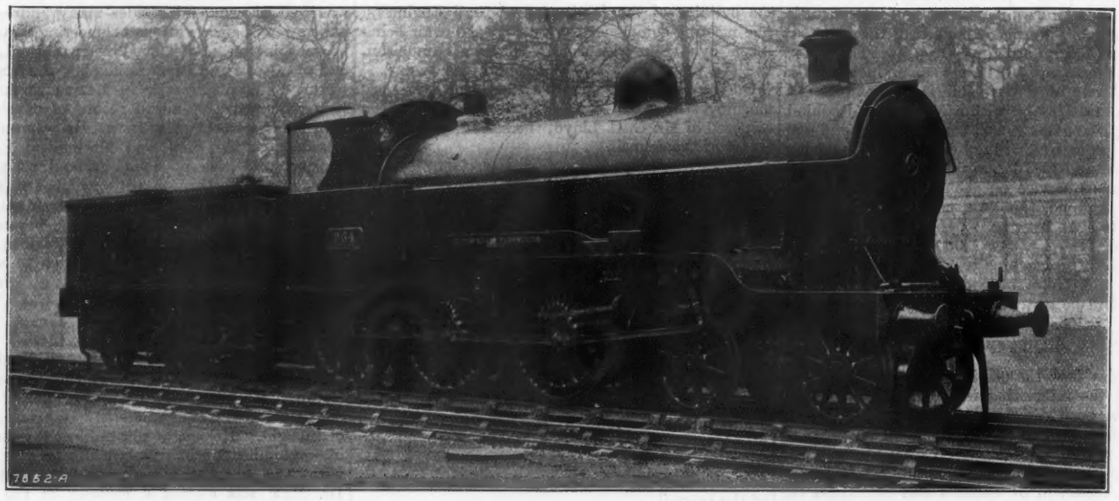
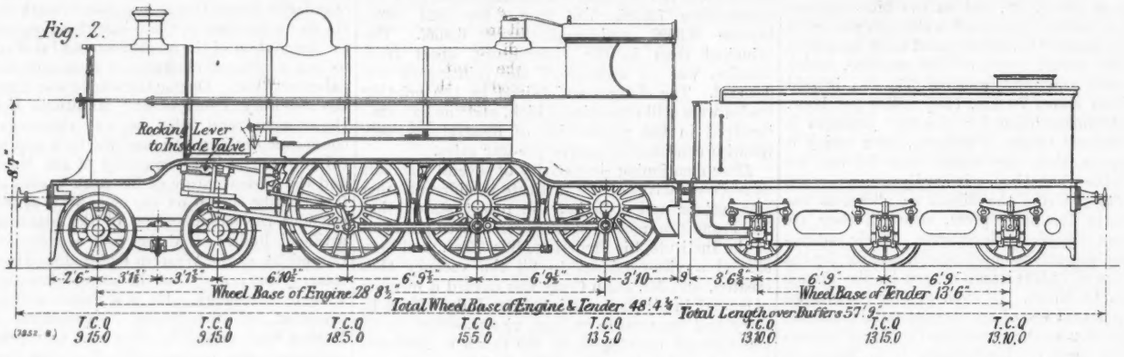


FIG. 1. 4-6-0-TYPE LOCOMOTIVE OF THE LONDON, MIDLAND AND SCOTTISH RAILWAY, FITTED WITH WALSCHAERT TYPE GEAR.



then was, going through the exhibits, and had learnt much from him. Later, they became intimate friends, and the friendship lasted until Sir Henry died. He was a man for whom the speaker had an unbounded respect—he possessed unlimited ability and energy. In conclusion, Dr. Maw repeated his expression of sincere thanks for the great honour which had been done to him.

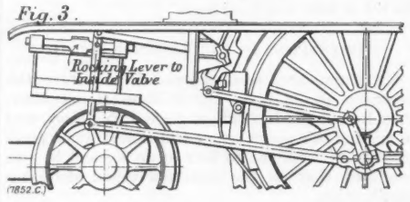
ALTERATION OF BY-LAW 10.

A resolution was then submitted; formal notice of this was given at the autumn meeting, held at York, on September 5, 1922. It related to the election of the president. The terms of the present by-law were as follows: "The president shall be elected for two years and shall not be eligible for re-election until after an interval." The terms of the resolution were: "That the by-law shall be altered as follows: 'The president shall be elected for one year,' and to omit the words 'and shall not be eligible for re-election until after an interval.'" On being put to the meeting this resolution was carried unanimously.

(To be continued.)

THE WALSCHAERT GEAR ADAPTED TO INSIDE CYLINDER LOCOMOTIVES.

THE Walschaert valve gear, which is admittedly an excellent type of motion possessing considerable advantages over the ordinary Stephenson link mechanism, is essentially a valve gear for outside cylinder locomotives. The reason for this is that by the use of the small return crank the need for a heavy eccentric is obviated, while the conjugate movement involving linkage with the crosshead would, in inside cylinder engines, result in interior complications, which



it is one of the aims of designers to avoid. An interesting adaptation of the gear, however, to inside cylinder locomotives has just been made under Mr. George Hughes, chief mechanical engineer, on the London, Midland and Scottish Railway. This gear has been designed by Captain H. P. Beames, mechanical engineer at Crewe, and is being fitted to six-coupled superheater passenger locomotives of the type illustrated in Figs. 1 and 2 above.

This adaptation, it will be seen at once, retains the Walschaert feature of ready accessibility of all parts of the motion for inspection or repair, and at the same time facilitates the work of oiling, &c., by the driver and fireman. The weight of the gear is slightly more than that of the ordinary Walschaert gear fitted to outside cylinder engines, but is still much below that of a double eccentric gear, and maintenance should be little, if anything, more than for the conventional Walschaert design. Compared with the Joy gear, which though an excellent motion, is not altogether satisfactory in maintenance, this gear has the great advantage of avoiding the necessity for any hole in the connecting rod, a feature which has proved a source of considerable trouble in locomotive practice from bent rods. The further advantage is claimed that it combines the advantages of an outside gear with the steady running characteristics of the inside cylinder locomotive.

The main features of the gear are illustrated in Fig. 3 from which it will be seen that the small return crank and eccentric rod are employed as usual, but that the 2nd or combination lever motion, usually taken off the crosshead, is derived from a light connecting rod coupled to the leading end of the coupling rod. The resultant conjugate motion drives a dummy spindle off which is worked an horizontal rocking shaft transmitting the motion to the valve spindle inside the rames.

The engines to which this gear has been fitted have cylinders 20½ in. by 26 in. and driving wheels 6 ft. 3 in. in diameter. The boiler pressure carried is 175 lb., the heating surface 1,511·6 sq. ft. with, in addition, 304 sq. ft. of superheater surface. The grate area is 25 sq. ft. The weight of the engine and tender in working order is 107 tons, and at 85 per cent. boiler pressure the maximum tractive force works out at 22,113 lb. Diagrams for runs between Crewe and Carlisle for a locomotive of this class show that on the Shap incline speed was well maintained, though on the journey north a stop for water had to be made at Oxenholme, and between Tebay and Shap the speed gradually fell from nearly 60 m.p.h. to about 20 m.p.h., the load behind the tender being 400 tons. Boiler pressure fell to 160 lb. on this section of the run, while on the southward journey the long climb up the bank was made at a more uniform speed, but the boiler pressure fell finally to 150 lb. The draw-bar pull registered on the incline on the latter journey ranged up to 5 tons, the 7-mile stretch at 1 : 125 between Penrith and the summit showing a fairly regular draw-bar pull at about 4 tons, with corresponding speed of from 50 m.p.h. to 35 m.p.h. The highest speed on the trips was over 80 m.p.h., and a considerable portion of the runs was made at speeds between 50 m.p.h. and 70 m.p.h., the actual running times being 3 hours 5⅝ minutes for the run from Crewe to Carlisle and 3 hours 8¾ minutes in the reverse direction. The distance is just over 141 miles, with various stops, and single-line working over a short portion of the line resulting in signal slacks and stops.

150-TON HYDRAULIC BENDING PRESS.

CONSTRUCTED BY MESSRS. HOLLINGS AND GUEST, LIMITED, ENGINEERS, BIRMINGHAM.

FIG. 1.

Fig. 2.

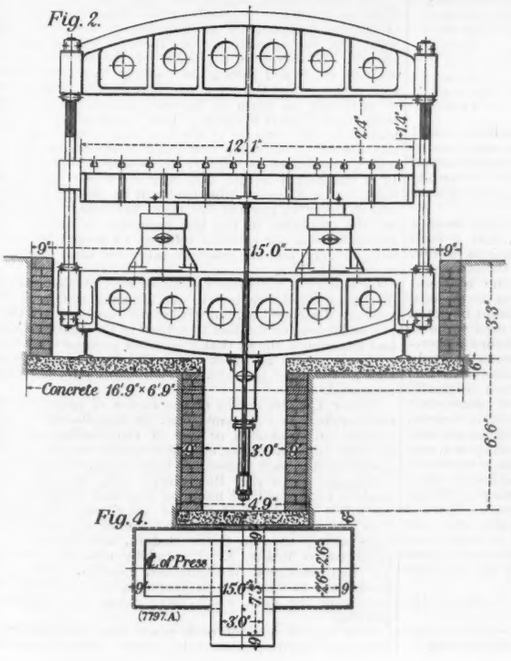


Fig. 3.

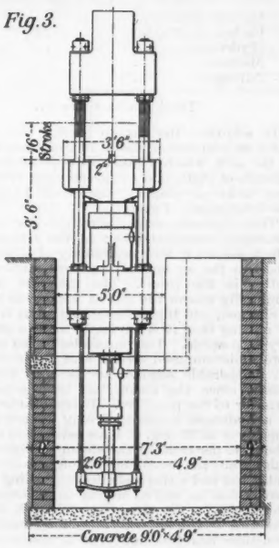


Fig. 4.

150-TON HYDRAULIC BENDING PRESS.

A HEAVY bending press, constructed by Messrs. Hollings and Guest, Limited, of Thimble Mill-lane, Birmingham, as part of a contract for the Butterley Company, Limited, of Codnor Park, Ironworks, is illustrated in Figs. 1, 2 and 3, on this page.

This machine was designed for bending steel plates used in the construction of colliery wagons. It is of 150 tons capacity and works with a hydraulic supply at 1,500 lb. per square inch. The general dimensions are shown in the two drawings.

The press heads are heavy castings of girder section connected by four mild steel columns of 4 in. diameter. The bottom flange of the press head has been kept as narrow as possible to permit of sharp angle working. The table is ribbed on the underside and provided on its top surface with Tee slots for use in bolting down the tools. It is effectively guided on the columns to ensure the correct registering of the tools.

The two main rams are of 12 in. diameter and have a stroke of 16 in. They are erected on the lower part of the frame and operate under the table. A quick return motion is obtained by the use of a drawback cylinder erected below the machine. The motion from this cylinder is taken to a crosshead connected by side rods to the table.

The foundation for the machine, as it will be erected at the ironworks, is clearly shown in Figs. 2 and 3.

BRITISH STEELWORKS GAS-PRODUCER PRACTICE.*

By FRED. CLEMENTS, M.Inst.C.E. (Rotherham).

CONSIDERABLE test work has been carried out on one of the three producers used in conjunction with one of the 60-ton Siemens furnace units of the Park Gate Iron and Steel Company, Limited, and the data obtained have been used to form a basis for technical comparison. The producer is of an old type which has been revised from time to time, as suggested by experience, in order to adapt it to the conditions of work. It is admittedly not without faults from a scientific standpoint, yet it is used for the purpose indicated with confidence, in view of the increasingly good results which have been obtained in the furnace practice for a number of years past.

It was determined that, as far as possible, all the data obtained should be quantitative, and therefore special arrangements were made to obtain accurately the following particulars by direct measurement:—

(*a*) The quantity of air blown into the producer.
(*b*) The quantity of steam used.
(*c*) A constant steam saturation temperature.
(*d*) A definite height of fuel bed.
(*e*) Gas analyses which should represent average conditions.
(*f*) The moisture, tar, and soot contents of the gas on leaving the producer.
(*g*) The temperature of the outgoing gas.
(*h*) The weight of coal charged and average samples for analysis.

In addition to the foregoing information the pressure was obtained at various points in the producer system, and also the amount of steam condensed in the blower-box was carefully measured and deducted from the gross amount, so that the actual weight of steam entering the fuel was correctly ascertained.

For the measurement of the air a Pitot tube together with a curved tube manometer was used, and for the steam an orifice type direct-reading meter. Both these instruments were bought from Messrs. George Kent and Co., Limited, of Luton, and were guaranteed accurate to within 0·5 per cent. They were sensitive to the slightest change in conditions, and were in every way satisfactory.

The coal was carefully weighed in a specially constructed box before being charged into the hopper, and the times of charging carefully noted on the log sheet. The gas samples for analysis, as well as those for the determination of the tar, soot and moisture contents of the gas, were obtained from the producer outlet neck. A testing staff was organised, and series of tests under different conditions of saturation temperature and depth of fuel bed were carried out. As the tests had naturally to be made without interfering with the work of the furnace, it was not possible to test the effect of any systematic alteration of the rate of gasification, but some difference naturally arose owing to the different conditions which obtained between one test and another. Readings were taken every 5 minutes, and logged on specially prepared sheets, and the results for each test were carefully averaged. The construction of the producer is of the simplest character. The advantage of this will be appreciated, since units of this description have been in operation for five years without any cessation of work for repairs. Special care is taken to prevent any wastage of gas. The coal hoppers are closed by means of machined lids, and patent steam-blown poking holes are used, so that the attendant can attend to the condition of the fuel bed without any loss of gas, and at the same time without personal discomfort. It should also be noted that this device enables him to see the fuel bed during the process of poking, and therefore ensures more thorough carrying out of the work.

Chemical Balance-Sheet.—The amount of steam

* Abstract of a paper read at the meeting of the Iron and Steel Institute, on Thursday, May 10.

decomposed is more with the 5-ft. fuel bed (57·5 per cent.) than with the 3-ft. 6-in. bed (47·2 per cent.), but in each case a considerable amount of the usefulness of the steam lies in its thermal influence as a cooling medium rather than in its chemical effect by decomposition. This point is borne out strongly by the series of tests.

Thermal Balance-Sheet.—The hot-gas efficiency is the value which is the most technically correct, considering a producer as a thermal machine, and in many types of furnaces where the sensible heat carried is usefully employed this efficiency can be taken as most nearly representing practical conditions.

In the case, however, of a furnace where the gas passes through regenerators the sensible heat carried is not of any great advantage, indeed, it precludes the use of gas regenerators of the most efficient design, since it is not economical to reduce the temperature of the chimney gases during recuperation below that of the producer gas which will be admitted during regeneration. At the same time, to adopt the cold-gas efficiency as the basis is equally incorrect since, if this be rigidly adhered to, it ignores the value of the tar mist and the finely-divided carbon which are always carried with the gas, and have an important bearing on the metallurgical value of the resulting flame. It is difficult to decide on the correct view to take as to the influence of the finely-divided carbon, or soot, on producer efficiency, since some of it settles in the flues and therefore never reaches the furnace. There is also some proportion of the tar mist decomposed during the passage of the gas through the regenerators, but not to the degree that is often assumed. It is evident from the test made at Park Gate that the temperature ruling above the fuel bed in a producer is of the order of 800 deg. C., and therefore the tar mist remaining at that temperature is mainly of the higher series, probably of the naphthalene group. These are relatively stable compounds and do not easily decompose.

A number of tests made in connection with the present investigation, for the purpose of comparing the composition of the gas before entering the regenerators and in the uptake to the furnace, failed to show any appreciable difference in the analysis. With regard to the relative amounts of tar and soot present, it was found that whilst the weight of the tar carried had decreased owing to decomposition, the total weight of carbonaceous matter was only slightly reduced. It seems reasonable, therefore, in order to make a fair allowance to cover unknown circumstances, to credit the producer gas with the whole of the calorific value of the tar mist and 80 per cent. of that of the soot carried in suspension as it leaves the producer. The remainder can be taken as lost in the flues and chambers.

It is recommended that a value for furnace gas efficiency should be adopted. This is determined as follows :—

$$\text{Furnace gas efficiency} = \frac{\left\{\begin{array}{c}\text{Calorific value of the cold gas} \\ + \text{ calorific value of tar} \\ + \text{ calorific value of 80 per cent. of soot}\end{array}\right\}}{\text{Total heat carried into the producer}} \times 100.$$

This expresses the value on a comparative basis applicable to any type of producer, and, in passing, it might be noted that the ordinary gas analysis is of little quantitative value unless the amount of tar mist and soot carried is determined at the same time and allowance made for it, as the effect of these is to increase the actual calorific value of the gas by an amount roughly equal to 10 per cent. of the calorific value of the cold gas. Series of tests were carried out with a view to investigating the effect of varying the steam saturation temperature with fuel beds of different depths. The results are largely what would be expected from theoretical considerations, but it is significant that the advantage of the 5-ft. fuel bed over the 3-ft. 6-in. bed is not very marked. The latter bed is, of course, much more easily worked from a manipulative point of view, and whilst the gas analyses and total calorific values for the deeper bed are a little the superior the difference is not very marked on the basis of furnace gas efficiency.

At 50 deg. C. saturation temperature the temperature of the hot zone became so high as to be almost unworkable, and, even with the excellent coal used, trouble was experienced with the clinkering of the ash, which involved additional poking. At the higher saturation temperatures, 65 deg. and 70 deg. C., the quality of the gas was reduced, and the amount of free moisture carried was excessive. The best results were obtained both in the producer and in the furnace when the saturation temperature was 55 deg. C. It seems, therefore, that when working with coals of reasonably good quality a saturation temperature of 55 deg. C. and a fuel depth of about 4 ft. is a combination which can be relied upon to give satisfactory results both in efficiency and in easy operation.

Efforts were made to determine the temperature at different zones in the producer bed, but all failed, owing to the difficulty of getting any metal tube, for protecting the silica tube of the pyrometer, to withstand the oxidising conditions and the high temperature developed in the hot zone. Test-bars were therefore employed, and from the observations made it was evident that, even at the higher values of blast saturation, the temperature attained in the hottest zone was greater than generally anticipated. Readings up to 1,400 deg. C. were observed at 55 deg. C. saturation temperature during the efforts to obtain the temperatures previously referred to. Gas samples were taken at the levels corresponding with those at which the temperatures were to have been obtained, but the results are not included in this investigation, as further experimental work is necessary before this essentially interdependent information can be correlated.

From the data obtained, however, it would appear that the time element is an important factor in the establishing of chemical equilibrium at any zone, and therefore it follows that in a producer of correct design the blast should enter the fuel in such a fashion that it passes relatively slowly amongst the incandescent carbon, especially in the early stages.

The various factors which go to make up the best type of gas-producing plant can be summarised as follows :—

1. The quality of gas should be uniform, and that most suitable for furnace work.
2. The gas should be available at the furnace regulating valve at a constant pressure.
3. The producer should require the minimum amount of attention both in operation and in maintenance.
4. The loss of unconsumed carbon with the ash should be a minimum.
5. The total capital, labour, and upkeep costs should be a minimum.

These factors are dealt with in sequence.

Factor 1.—It is the Siemens melting furnace which is particularly concerned in this investigation, and consequently the quality of gas desired is that which most efficiently performs the functions required of it in steel manufacture. The functions are that the gas should burn vigorously, and that the rate of transfer of heat between the flame produced and the materials in the bath should be a maximum. These conditions do not altogether depend upon the calorific power of the gas so much as on the radiating power of the flame, although in furnaces of modern design more advantage is now being taken of the contact of the burning gases with the metal. It is quite possible that a change in the gas composition which may result in a less calorific value may give a more efficient heat transfer in the furnace. Variation in the composition of the gas is only possible within relatively narrow limits, governed by the working conditions of the producer, but it is necessary to determine as far as possible what are the best conditions within those limits and to arrange for the producer practice to give the desired results.

There are four combustible bodies to consider, namely, carbon monoxide, hydrogen, methane and tar mist. The relative values of the carbon monoxide and hydrogen as combustibles have been frequently dealt with, and in view of the higher radiating power of the CO flame it is evidently desirable to increase the CO content and decrease the H_2 content as far as practicable. In accordance with the theory of producer-gas manufacture, the increase in the amount of steam added to the blast results in an increase of hydrogen and a decrease in carbon monoxide. It is therefore evident that the best results are obtained by working the producer at as high a temperature as possible, and with the lowest steam saturation value permissible. The methane and tar mist are both products of direct distillation, and depend more on the character of the coal used than on the working methods of the producer. Naturally a coal containing considerable volatile matter will give a higher amount of tar in the gas although, as previously indicated, the character of the tar will depend upon the temperature of its distillation, or, in other words, on the temperature of the upper layers of the fuel bed. Since these upper layers are hotter with a shallow fuel bed, it can be taken that the depth of the fuel bed is a factor in the methane and tar mist contents of the gas. The value of the tar mist is not only measured by the increase in the total calorific power of the gas, but chiefly by the fact that its presence ensures the luminosity of the flame and therefore increases its radiating power.

A gas composition which would give very satisfactory results in a furnace is as follows :—

	Per Cent.
Carbon dioxide	5·0
Carbon monoxide	28·0
Hydrogen	10·5
Methane	4·5
Nitrogen	52·0
Total combustibles	43·0

In addition, the gas on leaving the producer would carry in suspension about 15 grammes per cubic metre of tar mist, which if taken as naphthalene would have a formula of $C_{10}H_8$ and a calorific value of 9,400 Centigrade heat units per pound; also about 10 grammes of soot per cubic metre of gas.

The moisture carried with the gas can only have a secondary chemical effect in the furnace, and if such effects do occur they are mainly of a deleterious nature. The less the amount of moisture carried, therefore, the better is the result. The moisture in the coal undoubtedly enters the gas as vapour as soon as the coal is charged, and this is inevitable; but it should be noted in passing that it is advisable for the coal used to be as dry as possible. The remainder of the moisture is therefore undecomposed steam, and this represents not only an undesirable adjunct to the gas, but also is a fuel waste, since the steam has been generated originally exterior to the producer. It is admitted, of course, that if a hydrogen content of only 10 per cent. is desired, then even at 55 deg. C. blast saturation temperature only about 50 per cent. of the steam can be decomposed, and this entails the remainder passing into the gas as moisture; yet it has had a thermal effect in cooling the incandescent bed of fuel as well as helping to disintegrate the clinker. Reference to the paper on "British Siemens Furnace Practice"* will show at once the considerable effect the moisture has thermally, as a result of its high heat capacity; but this effect is strongly negative, and there would be a decided gain to the furnace if the moisture in the gas could be eliminated.

The conditions necessary for uniform results of the character just outlined are as follows :—

(*a*) A fuel depth sufficient to ensure adequate contact between the gases and the fuel.

(*b*) The velocity of the gases to be low enough and the zone temperatures high enough to provide for the sufficiently long time of contact, and for the thermal conditions necessary to ensure chemical equilibrium.

(*c*) The use of fuel of proper size (graded between 1-in. and 2-in. mesh) evenly distributed, so that all parts of the bed work freely.

(*d*) The possibility of channelling of the gases through the burden to be provided against.

(*e*) The blast saturation temperature to be evenly maintained. Its value should be only just high enough to ensure the proper working of the fuel, whilst keeping the amount of undecomposed steam passing into the gas as moisture as low as possible.

Factor 2.—The amount of gas required during the progress of working a charge in a Siemens furnace varies, and consequently the furnace operator controls this with the regulating valve. If, however, the producers continue to generate gas at the same rate during the whole time it is obvious that, when the furnace is not taking the normal requirements, the pressure in the producer rises considerably, and the opposite effect occurs when the furnace is demanding the maximum amount of gas. Again, during a period of regular work it is distinctly advantageous for the furnace operator to be able to set his gas and air valves so as to give the combustion desired, and then to be confident that the conditions will remain unaltered. It is therefore desirable that the rate of production of gas should be directly and automatically governed by the gas pressure at the regulating valve, and means for controlling the steam and air inlet to the producer should be provided. If adequate provision is made at the producer no difficulty need arise in arranging for the control by the gas pressure.

Factor 3.—Naturally, in order to provide for a supply of gas of uniform quality, the conditions within the producer must be maintained uniform. Logically this emphasises the need for continuous feeding of the coal, even distribution over the whole of the bed, and automatic poking. It is admitted that the modern types of mechanically operated producers have been designed with a view to achieving the ideal conditions outlined, and whilst this is done to a varying degree of success it must not be lost sight of that the attainment involves the use of considerable machinery, which is expensive in first cost and also requires maintenance. It is doubtful economy to reduce the charge for semi-skilled labour on the producer and replace this by a charge for skilled labour in repairs. It is a matter, therefore, for close investigation whether a non-mechanically charged producer, intelligently operated, is not a more economical installation in the final analysis of the cost of production. In general practice it is possible to get from a non-mechanical producer, when intelligently operated, gas of equal quality to that produced in mechanical units, and it may be worth while to sacrifice something of the ideal for the sake of lower production cost.

Factor 4.—The reduction of the loss of carbon with the ash to a minimum is not easy of attainment. The consideration only of the proportion of carbon in the ash is not sufficient to reveal the true loss, since the actual incombustible carried in the coal has a bearing on the matter. The loss of 5 per cent. of carbon in the ash from a coal containing 10 per cent. of non-combustibles represents a net loss per ton of coal charged equal to 10 per cent. of carbon in the ash from a coal containing 5 per cent. of non-combustible. This fact is frequently lost sight of, and the only useful comparison is the carbon lost per ton of coal charged.

The observations during the Park Gate tests on the different zones in the producer confirmed that the zone of highest temperature is immediately above the ash zone, and the transition from the one to the other is abrupt. If, therefore, a portion of the carbon is not entirely consumed during its passage through the hot zone and it enters the ash zone, there is little opportunity of gasifying it, since it becomes almost immediately submerged in inert material. It is conceivable, however, that the lower stratum of the hot zone is made up of a mixture of combustible and incombustible material, in which the latter is rapidly increasing in proportion. It is the action within this stratum which determines the amount of combustible that will be lost in the ash, and in order to provide the most favourable condition for the oxidation of the last remnants of carbon it is desirable that the stratum referred to should be blown with air only, and the moisture saturated blast should be introduced above it.

Ostensibly a producer provided with mechanical ash discharge should reduce to an absolute minimum the amount of carbon lost, but with many classes of coal there is a tendency for the bed to cohere in the upper regions, and experience shows that it is often necessary to resort to hand-poking to break down the burden, and when this is the case the loss of combustible is materially increased.

Factor 5.—The choice of the means of producing gas lies between two systems, viz., an installation of non-mechanical producers or one of the mechanical type. In order to arrive at an effective comparison, a complete installation of each system has been designed for identical conditions of work. Both have been arranged with modern equipment for handling coal and ashes, and can be taken as representative of their respective types. The Kerpely producer has been taken as a representative type widely used in Great Britain, and the author is indebted to Messrs. E. G. Appleby and Co., Limited, 70, Victoria-street, Westminster, London, S.W. 1, for their kind co-operation in preparing the drawings and supplying the data which have made the comparison possible.

The capital cost of each plant has been accurately obtained, based on present-day prices; that for the non-

* ENGINEERING, vol. cxiii, pages 579, 593 and 758.

mechanical plant being supplied by Messrs. Markham and Co., Limited, Chesterfield; Messrs. Appleby and Co., Limited, having provided the cost for their own design. In view of the greater amount of machinery involved in the mechanical plant, an annual depreciation of 10 per cent. of the capital cost has been allowed, whereas in the non-mechanical plant 7½ per cent. has been taken. This is deemed to be an equitable allowance.

The details of the cost of gasification per 1,000 tons of coal show that the cost is slightly higher on the non-mechanical plant. It should, however, be noted that no allowance has been made for incidental labour, though from returns of operative practice it is clear that hand-poking has to be resorted to on mechanically-operated plant. The result of this is that the labour cost of gasification per 1,000 tons of coal is much the same as on the non-mechanical plants. It is not desired to press this as a point in favour of the non-mechanical plant, but it is one which it is necessary to consider closely. Possibly in each case there are special local circumstances which in some measure may account for the results.

Further, the question of the cost of repairs deserves attention, and whilst it is admitted that the latest designs of mechanical producers have been developed with a view to reducing the liability to mechanical failure, the service is of such a nature that the wear on the moving parts is likely to call for maintenance by skilled labour.

In conclusion, the author trusts that the experimental and operating data, as well as the scheduled experience of present-day practice, may be useful in determining future policy. In view of the varying conditions of quality of coal and its differing physical character, it is impossible to outline any axioms which would be applicable to all cases. Each therefore must be examined in the main on its merits.

THE INTERDEPENDENCE OF ABSTRACT SCIENCE AND ENGINEERING.*

By Sir RICHARD TETLEY GLAZEBROOK, K.C.B., M.A., D.Sc., F.R.S., Hon. M.Inst.C.E.

I WISH in the first place to express my cordial thanks to the council for the honour conferred on me by the invitation to deliver this lecture. The Secretary wrote, telling me of the subject of the first lecture delivered by Sir William Anderson thirty years ago, "The Interdependence of Abstract Science and Engineering," and stating that "the President feels that this would be a good opportunity to deal with scientific research in relation to engineering practice, and especially with the organisation, methods and application of engineering research." I welcomed the opportunity. Some twenty happy years of life had been spent in the attempt to apply science to industry, chiefly engineering industry; and the thought of being able to speak on such a subject in this hall was an alluring one. I accepted gladly, but without reading Sir William Anderson's lecture; when I studied it, I was appalled at the task lightly undertaken. His lecture covers an immense extent; it rests on the experience gained in a long and active life devoted to his profession; it is illustrated by reference to questions and difficulties outside my ken; it is full of knowledge obtained by the study of many problems in science and economics and by the application to these of an acute and critical mind. I cannot hope to treat the subject in a manner which will bear comparison with the skill and ability applied to it by my predecessor. Still, I will do my best; let me commence by quoting the conclusion of his lecture:—

"I have endeavoured to show," he said, "how the history of abstract science by which I intend to designate the history of researches entered into for the sole purpose of acquiring knowledge of the operation of Nature and her laws, without any thought of reward or expectation of pecuniary advantage, has had its reflex in the records of the engineering profession, and how the most recondite investigations, apparently unlikely to have any direct influence on our practice, have, in course of time, become of cardinal importance. I have also ventured to point out how in these days the engineer must banish from his mind the idea that anything can be too small or too trifling to deserve his attention. 'Nothing is too small for the great man' is, I am told, written over the cottage once occupied by Peter the Great at Saardam. The truth embodied in that legend should ever dwell in our minds, for success, I am persuaded, lies largely in close attention to details."

Or, again, referring to the views of Mr. Forrest himself: "You cannot touch anything in natural science which will not, sooner or later, prove of advantage to the members of this Institution, and which the engineer will not, in time, turn to the moral as well as to the material advantage of the human race."

The experience of the last thirty years has all tended to confirm these views. It is my task to-night to give some few illustrations of the truth of the principles advocated by Sir William Anderson, and to trace some of the effects those principles have had on engineering practice. This effect has shown itself in many forms. The education of the engineer has been greatly modified in consequence. Institutions devoted to the application of science to industry have grown and multiplied. The State has recognised something of its responsibility; and private persons, public men, and industrial associations have given many proofs that now their importance has been, at least in part, realised. As one of the most striking of these proofs let me mention the recent generous gift to the Royal Society of Sir Alfred Yarrow, a gift intended for the advancement of abstract science—natural knowledge—to use the phrase by which it is known in the Charter of the Society.

By establishing the William Froude tank at the National Physical Laboratory, and by the researches which led to the water-tube boiler and the torpedo-boat destroyer, Sir Alfred had already shown his appreciation of the value of science. May I, as a scientific worker, rather than as an engineer, thank him for all he has done.

But before referring in detail to some of the modern applications of abstract science to engineering, let me briefly consider these various connecting links. And first education. Sir William, after referring to the importance attached to the scientific education of an engineer by this Institution, deplores the fact that "except, in the noble endowments of the City and Guilds Schools and the Government institutions at South Kensington," in London the movement to secure the necessary training "languishes for want of adequate support." What are the conditions at present? The South Kensington Institution and the City Guilds College now form the Imperial College of Science and Technology, and the Registrar of the City and Guilds College—the Engineering Department of the Imperial College—has kindly furnished me with some details. The college opened in 1886 with 35 students, of whom 8 were reading chemistry. By 1893 the numbers had increased to 205, including 10 chemistry students and 32 special and post-graduate men. In 1911 the chemistry students were transferred to the Chemical Department of the college. At the end of the past complete session (July, 1922) there were 492 engineering students in the college, including 60 special and post-graduate men, while 138 students of the Royal College of Science and the Royal School of Mines were also receiving instruction; thus the total number was 630. During the period under review 563 students have taken the Internal B.Sc. degree in Engineering of the University of London, and of these 309 have graduated in honours. In addition, a certain number have obtained the External degree.

The academic registrar of the University of London has been kind enough to send me the following statistics as to the B.Sc.(Eng.) degrees of the University since its reconstitution in 1900:—

	Internal.		External.	
	Pass.	Honours.	Pass.	Honours.
1903	0	5	4	1
1922	168	74	89	39
Totals 1903–22* ..	672	622	509	247

Of the above totals 51 internal degrees and 25 external were war degrees. The figures* show the immense growth since 1903.

As to the rest of London, conditions have altered since 1893. The following summary supplied by Sir R. Blair, the Educational Officer of the London County Council, gives details for 1913–14 and 1921–22:—

TABLE I.—*Engineering Students in London.*

	1913–14.	1921–22.§
1. Professional students (day):		
University institutions ..	718	981
Polytechnics	506	725
	— 1,224	— 1,706
2. Evening and part-time day ..	6,580	8,863
3. Day trade schools	981	1,021
4. Other evening institutes ..	1,521	2,556
Total students	10,306	14,146

§ These members are somewhat increased owing to facilities offered for discharged officers.

The numbers show a great improvement on the condition at the date of the first James Forrest Lecture. When, however, we realise that before the war there were some 175,000 persons employed in engineering trades in London, of whom about 50,000 were under 25 years of age, while the number of persons dependent on engineering industries—workers and families—was in 1916 about 750,000, they seem small enough. The numbers of students in some other engineering centres may also be given.

In pre-war days the Royal Technical College, Glasgow, had 238 day students and 1,994 evening engineering students. Affiliated to it were institutions with 9,820 engineering students. At the University of Manchester there were 57 students in 1893; the number at present is 148. A limit of 150 is fixed by the size of the laboratories. The Manchester Technical College began work in 1906, with 5 candidates for a degree in mechanical engineering and 28 for a certificate. In the present session the numbers are 71 and 7 respectively; again in electrical engineering, while in the first session there were 16 degrees and 40 certificate candidates, in 1922–23 the numbers were 87 and 8 respectively.

Figs. A and B (page 600), which I owe to the kindness of Professor Inglis, show the growth of the engineering school at Cambridge since 1894. In that year there were some 50 students in the school, and 7 honours graduates. In 1920 the students numbered 800, and at present† are rather over 600, while the number graduating in honours in 1922 was 125.

Professor Inglis writes: "There is no doubt that employers in all directions are attaching increased importance to a university training. Some firms go so far as to say they will not take a man on their staff unless he possesses a university degree. This attitude is growing steadily, and it has become accelerated since the war. The general demand is for a youngster who has had a good all-round training." In America there is more than one college with from 1,250 to 1,500 students. At Charlottenberg before the war the number was 1,500.

The educational scheme in London covers a wide range. In the university institutions a large proportion of the students are reading for the B.Sc. degree; in the polytechnics the proportion is, of course, less—a diploma in engineering is the more usual aim.

In the report already alluded to Sir R. Blair points out that it is generally recognised "That in addition to the course of more strictly engineering subjects—wide enough in itself—the professional students of engineering must have an acquaintance with modern languages and with economics, including questions of cost of production and of management of labour."

Of the evening classes some are intended for men who hope to proceed to a university degree, but cannot afford whole-time study, and in these an advanced stage of instruction is reached. Others again aim at fitting for their work large numbers of foremen and skilled artificers. The technical training of workmen in the engineering trade is carried on mostly in evening classes; and in many of these mathematics and drawing, together with, in some cases, chemistry and physics, have a prominent place.

Part-time classes for apprentices have been arranged in connection with various large works; perhaps the most complete scheme is that run at the Woolwich Polytechnic for the trade lad at the Royal Arsenal. It includes mathematics, mechanics, engineering drawing, electricity and magnetism, and chemistry, and the work done is considered along with the works reports when dealing with promotion. Another such scheme is that of the Gas Light and Coke Company for gasfitter apprentices, described in a paper by Mr. Goodenough, read before the Institution of Gas Engineers in 1913, entitled "Creating an Outdoor Staff." Up to the present 330 trained under the scheme have entered the shop, about 30 have been promoted to the staff, and 30 are now in training. In this course, and in the apprenticeship schools established by the council in various localities, in addition to the subjects mentioned above, English forms a prominent subject of instruction. Thus, while I would press strongly the hope that the efforts made since 1893 to extend the knowledge of the fundamental principles of engineering should in no way be relaxed, the advance has been very considerable. A serious attempt has been made to impart more "than the slender amount of theoretical knowledge," asked for by Sir William Anderson, "to the various grades of employment," and the attempt has, I claim, met with success. As evidence of this, let me quote a few words from a report by Mr. M. F. Ryan, Director of Munition Gauges, Ministry of Munitions, to whose great organising skill and tactful handling of every source of supply the country owes a great debt. Dealing with the question of gauges, he writes: "The success of the London County Council in their supply organisation was greater than that of any other training sections in the country." . . . "The national asset underlying this success is a body of men possessing a high degree of manual skill in addition to well-educated minds and capable of transmitting their skill and knowledge to others." . . . "Possessing a high degree of manual skill," a quality no less necessary than high academic training, for without works experience no student can become an engineer, and the unanimous conclusion of the committee of this Institution, which some years since reported on the training of an engineer that "Engineering training must include several years of practical work as well as a proper academic training," nowadays perhaps needs specially enforcing.

Nor is the view that science must go hand in hand with practice confined to the heads of the engineering profession only. At the Trades Union Congress at Southport in 1922 a report on apprenticeship was presented from the shipbuilding, engineering, iron and steel, and building group of the General Council. After referring to the difficulty found in many large areas in obtaining instruction other than that provided in the workshop, especially in cases where part-time training is required during the day, the report continues: "It is now generally accepted that if industry and commerce are to progress the workers engaged therein must be allowed to exercise their intelligence," and suggests the following grading for apprenticeships:—

(1) The trade school, providing for workshop training and constituting a selecting ground for testing the capabilities of the apprentice.

(2) The technical school, where instruction of a scientific and theoretical nature would be given.

(3) The universities or higher technical colleges for supplementary training of apprentices of proved special ability.

This, it will be noticed, is practically the scheme in existence in London under the County Council.

Again, several of the Joint Industrial Councils—the Whitley Councils—have given special consideration to problems of education and research, and have appointed committees to deal with them. The report establishing the councils specifically mentions "industrial research and the full utilisation of its results" as one of their objects. Prominent among such are the Pottery and Building Trade Councils. A sub-committee of the Pottery Council dealing with research, inventions and design, recently recommended the establishment of a 50*l.* scholarship.

Some of the trades unions, notably the Association of Engineering and Shipbuilding Draughtsmen and the Electrical Trades Union, have shown by articles in their

* The twenty-ninth James Forrest Lecture, delivered at the Institution of Civil Engineers, on Friday, May 4, 1923.

* These figures include the degrees of Imperial College students already mentioned.

† The fall is due to the absence of service students.

journals their appreciation of the importance of science as an element in progress, while others have taken great interest in the applications to workers of modern psychological research; in a recent article Mr. W. Graham, M.P., emphasised the importance for the world of the possibilities which trade unions have before them in "the scientific study of what is not very happily termed industrial fatigue."*

In reply to an inquiry as to the attitude of the workers towards science in relation to industry the secretary of the Iron and Steel Trades Confederation writes, after a reference to the appreciation shown by the men of classes provided by local education authorities, "The old-fashioned workman who was content to plod along by rule of thumb, and who had no desire to learn anything of the processes which gave him employment, is disappearing, and even that type of man is so far aware of his own deficiencies that he is making tremendous sacrifices so that his sons can have a scientific education. This is evidenced by the number of applications for places in secondary and technical schools, the applications far and away outnumbering the places available."

Again, the assistant general secretary of the union of Post Office Workers writes thus:—

"So far as it is possible for me to speak in general terms on behalf of our members, I should say that we as an organisation are keenly alive to the interdependence of science and industry.

"Our attitude as a union towards science and invention is not one of resistance, but we hold the view very strongly that the social advantage resulting from an improved process should be, to some extent at least, secured for the alleviation of the lot of the industrial worker.

"To-day, scientific development usually carries with it a simplification of process and a reduction in the wages standard. In our view the gain due to the introduction of improved machinery should be devoted in part to the improvement of working conditions."

For my part I am glad to take this opportunity of expressing my own agreement. It is, in my opinion, an essential condition of progress, and, as scientific men, we have no desire to deny the workers their fair share in the results due to our advance.

Another matter of great importance is the supply of trained workers who will bring to their duties in factories and workshops a knowledge of scientific principles and an acquaintance with scientific methods.

The scheme of industrial bursaries started in 1911 by the Royal Commission for the Exhibition of 1851 has this for its object. One of the difficulties which confront a student from a university or technical college who desires to become an engineer arises from the small pay of an apprentice. At first he is worth but little to his firm, and his pay is in proportion to his worth. The Commissioners offer each year to a large number of university institutions nominations to bursaries to be awarded to students who have done well in some branch of science and who propose to go into works. Each student before receiving his emolument must be placed in some position approved by the Commissioners, and the amount of the bursary depends on his means and on the pay he receives from the works; it is the intention of the commission to bring this up to a living wage. At present the nominal sum is 150*l.*, which may at the discretion of the commission be raised to 200*l.*; the actual sum varies with the other conditions of the applicant. The bursary usually lasts for two years, at the end of which it is supposed the worker should be in a position to support himself. The scheme was inaugurated in 1911. In the following three years 63 graduates of the various universities were enabled to enter the engineering profession, bringing with them the scientific knowledge acquired during three years successful academic training. The scheme was suspended during the war, but is now in active operation again; and up to December 31 last about 19,000*l.* had been expended in the assistance of 185 bursars. The complete list is most interesting reading; without this help few, if any, of the candidates could have become engineers; their parents' income varied from 75*l.* a year up to 500*l.* or 600*l.* Quite a considerable proportion now hold responsible and well-paid posts.

The scholarships established years ago by Sir Joseph Whitworth are almost too well known to need special reference. They operate in the opposite direction to the bursaries scheme, in that they offer opportunities of a college training to men with works experience.

Among the agencies doing most valuable work in the introduction of men trained in science and literature to the engineering and other industries must be reckoned the appointments boards of the universities. The Cambridge University Appointments Board† was established in 1902, at first in a tentative manner; it became a permanent board in 1906, and since that date has been increasingly active. It consists of representatives of the university and of industry, and has throughout received great assistance from engineers and men well known in the business world, who have voluntarily placed their services at the disposal of the university.

According to its last report:—"In the year ended December 31, 1922, 373 appointments were obtained on the introduction of the Appointments Board. The appointments were distributed as follows:—

Government departments	13
Administrative appointments in commerce and industry	94
Manufacturing and technical appointments	87
Colonial administration	16
Secretaryships	2
Agriculture and forestry	16
Indian and Colonial railways	12
Public works department and surveys ...	7
Railway traffic	3
Journalism and publicity	5
Publishing	3
Articled clerkships	3
Museums	3
Miscellaneous	1
Educational appointments	120"

Men who intend to take up the engineering profession usually obtain their degree in honours in the mechanical

Fig. A. TOTAL NUMBER OF STUDENTS ATTENDING DEPARTMENT.

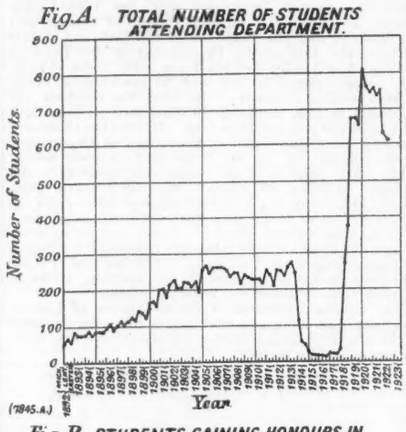
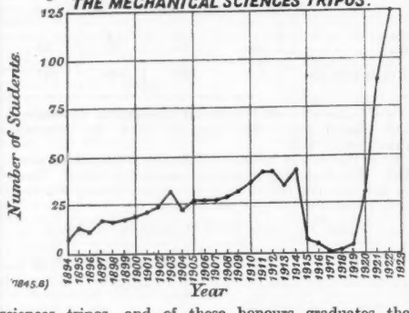


Fig. B. STUDENTS GAINING HONOURS IN THE MECHANICAL SCIENCES TRIPOS.



sciences tripos, and of these honours graduates the following are lists for the past three years:—

MECHANICAL SCIENCES TRIPOS, CAMBRIDGE, 1920–1923.

1920. *Number of Graduates*, 30.

Directors or partners in manufacturing concerns	1
Subordinate positions in manufacturing firms (ranging from draughtsman or works-managers' assistant up to works-manager	15
Assistants to consulting engineers ...	3
Assistant teachers	1
In service of Government, municipalities or railway companies in the British Isles	5
Miscellaneous	1

(Four occupations unknown.)

1921. *Number of Graduates*, 92.

Pupils or apprentices	38
Salaried posts (Government commercial, Government engineering services abroad, teaching, patent agents)	42
Employment other than engineering ...	1
Family business	8

(No record of three people.)

1922. *Number of Graduates*, 123.

Pupils and apprentices	37
Salaried posts	38
Still at Cambridge	9
Obtained own opening	30
No employment	9

In connection with the work the Secretary writes:—"In industry we are continually and increasingly being asked for men, if not highly-trained research men, at any rate sufficiently grounded in the elements and terminology of science, to consider the problems of production from a scientific point of view. I have before me to-day (March 26, 1923) a letter from a prominent telephone company asking for such a man; last year by far the largest manufacturers of hosiery in the world were looking for a first-class physical chemist to study the question of shrinkage; the Calico Printers' Association and the large cotton firms generally are concerned to investigate the scientific reasons as to why a certain kind of sizing is necessary to get the best results when dyeing. A large cocoa firm, to name only one other from a very large number of similar inquirers, were seeking a scientifically-trained man to investigate the chemistry of the natural fermentation of the bean within its pod, the whole flavour and working state of the bean depending on the best moment of arresting this process. Nor must one omit to mention the research being carried out by the large oil companies both on their own and through us in Cambridge, and by individual workers of distinction such as Ricardo at Shoreham."

These instances are, it is true, not all engineering, but enough has perhaps been said to indicate the close interdependence between exact science and all forms of industry; and the evidence of other similar boards might be quoted to the same purpose. Turning next to institutions and associations designed to promote the application of science to industry, it is not improper, I trust, for me to place first the National Physical Laboratory, and I do this the more readily, speaking in this hall and to this audience, because of the intimate connection which has existed between the Institution and the National Physical Laboratory since its foundation. Your representatives on the general board of the Laboratory have been your past presidents—Sir John Wolfe Barry, Sir William Preece, Sir William White, Professor Unwin, and Sir Robert Elliott-Cooper. Nor are these all the members of your council who have given unstinted help. Dr. Maw has served for long on the general board and executive committee. Colonel Crompton, ever young, is almost a perpetual member, and his enthusiasm has inspired and supported many of our most interesting undertakings. Sir Benjamin Baker, Sir Andrew Noble, Sir Frederick Donaldson, Sir Maurice Fitzmaurice, Captain Sankey, Sir Henry Oram, Sir John Aspinall, Sir Archibald Denny, Sir Robert Hadfield, Mr. Alexander Siemens, Sir John Snell, Sir Alfred Yarrow, Sir Charles Parsons, Sir Dugald Clerk and Sir William Ellis are some of those to whose assistance success is due. Mr. Basil Mott, the disigner of the Froude tank, has helped our work in a marked degree.

I am asked to deal with the organisation, methods, and application of engineering research. Some of you have probably seen the latest report of the National Physical Laboratory, a document of over 200 pages, submitted to the General board some six weeks since. On looking through it, I felt that the easiest way to discharge the duty laid before me by the Council would be to read extracts from that Report. I do not propose to take that course, though I shall make use of it when dealing later with some of the recent applications of science to engineering. For the present let me refer briefly to the history of the Laboratory, its work, and its organization. In 1893 the Laboratory was not: it existed only in the hopes and imagination of a few enthusiasts. At the British Association at Cardiff in 1891 Sir Oliver Lodge, in his address as President of Section A, had referred to the need, and outlined some of the work for the Laboratory. "The further progress," he said, "of physical science in the somewhat haphazard and amateur fashion in which it has been hitherto pursued in this country is becoming increasingly difficult; the quantitative portion especially should be undertaken in a permanent and publicly-supported laboratory on a large scale."

The seed germinated slowly: the late Sir Douglas Galton, in his presidential address at Ipswich in 1895, pressed the same view, contrasting our position with that in Germany. A British Association committee was set up, with Lord Rayleigh as chairman, which reported in 1896. Lodge was the secretary. Its unanimous conclusion was that—"If England is to keep pace with other countries in scientific progress, it is essential that such an Institution should be provided, and this can scarcely be maintained continuously on an adequate scale except as a national laboratory, supported mainly by Government." Lord Salisbury appointed a Treasury Committee representative of science and industry; and its report that a public institution should be founded for standardising and verifying instruments, for testing materials, and for the determination of physical constants was approved by the Government. The committee had examined more than 30 witnesses, and their evidence was conclusive as to the need of close co-operation between science and industry. The interdependence of the two was recognized. One American writer, speaking of the growth of German industry, assigned as a principal cause the perfect alliance between science and commerce existing in that country. "Science," he says, "there no longer seeks court and cloister, but is in open alliance with commerce and industry"; and in a lecture given shortly after before the Royal Institution I wrote: "It is our aim to promote this alliance in England, and for this purpose the National Physical Laboratory has been founded."

The scheme of organization was admirably adapted for its ends. The ultimate control was vested in the president and council of the Royal Society, who were to act through a general board and an executive committee. The board consists of certain official members, six in number, and 36 ordinary members appointed by the council of the Royal Society. Of these twelve are nominated by the six leading technical societies*; the remaining 24 are selected by the council from men of science and leaders in industry and trade, who need not be—many indeed are not—Fellows of the Society. The executive committee of 12, with certain officials, is appointed from the board with the proviso that half the ordinary members must be selected from the representatives of the technical societies.

The executive committee was to have the immediate management of the Laboratory, and was responsible for

* I owe much of this information to the courtesy of Mrs. Wootton of the Research and Information Department of the Trades Union Congress.

† An interesting account of the pre-war work of the Board will be found in a paper by the secretary, Mr. H. A. Roberts, on "Education in Science as a preparation for Industrial Work," Royal Society of Arts, March, 1912. Reference may also be made to the Reports of the Board published annually in the Cambridge University Reporter.

* These are the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Iron and Steel Institute, the Institution of Naval Architects, and the Society of Chemical Industry.

its finance. The director was responsible to, and took instructions from, the executive committee, but, subject to such instructions, had the sole direction and control of the officials of the National Physical Laboratory and of the work done within it. Such was the scheme, and under this scheme the Laboratory worked until 1918. Sir Arthur Rücker and Mr. S. E. Spring Rice, of the Treasury, took the main part in its preparation, and it is a privilege to put on record my testimony to the value of their work.

But in time the building spread beyond its foundations. Conditions during and after the war altered; the financial responsibility became too great for the Royal Society to bear.* In 1900 the ordinary expenditure was 5,479*l.*; by 1913–14 it had grown to 38,003*l.*; and since the war it has largely exceeded that amount. The value of the work done for which payment is received now approaches 100,000*l.*

Thus a change was necessary, and in 1918 the Laboratory became a Government institution: the responsibility of the Royal Society ceased. The general board and the executive committee, though appointed by the president and council, are responsible to the Department of Scientific and Industrial Research; the real control rests in the hands of the officers of the department and of its advisory council.

During the period 1900–1914, 13 volumes of scientific researches were published. We began in a small way with two departments—physics and engineering—and a staff at the end of 1901 at Bushy House, of the director, eight scientific† assistants, an accountant, four mechanics, and an engine-driver—in all, 15 people. In addition, Kew Observatory, with Dr. Chree and staff of 16, formed the Observatory Department.

According to the report for 1922 there are now eight departments at Teddington, each with its superintendent or head and staff of scientific assistants, observers, and other workers, in all,‡ 484 persons; the buildings consisted of Bushy House and a small workshop; now they constitute a small town. At the start the expenditure was small, salaries were low; in fact, one technical journal, commenting on the terms of appointment, anticipated that "the duties will be equally light." As to the organization, in those days it was simple; the director was able to keep in close touch with everything that went on; the staff worked as a whole, discussing and consulting with each other as difficulties arose. We were a team working with a common object inspired by the belief that the application of science to the industrial problems set before us was of supreme importance, and ready to devote ourselves to that end. That spirit animated the work for 20 years, and on its maintenance depends in great degree the future of the laboratory. It exists still, though under altered conditions, brought about in part by the natural growth of the Laboratory, in part by its connection with a Government department. Freedom from financial troubles has been gained; freedom to develop under the fostering care of the Royal Society is replaced by the task of working under Treasury conditions imposed on the executive and the staff alike.

I propose to return later to the researches carried out in recent years and pass on to some of the other organisations established in late years for the promotion of science in its application to industry. Reference has just been made to the Department of Science and Industrial Research, which now forms a most powerful agency connecting science and industry.

A committee of council dealing with industrial and scientific research came into existence first under the auspices of the Board of Education, when Mr. Pease was President of the Board. At a later date it was connected with a department of its own. On December 1, 1916, a deputation from the Conjoint Board of Scientific Societies, headed by Sir Joseph Thomson, President of the Royal Society, waited on Lord Crewe in this hall. Sir J. J. Thomson, in his address, dealt with the importance to industry of research in pure science; he was supported by Sir Maurice Fitzmaurice, the president of this Institution, speaking on behalf of engineering, and by Professor H. B. Baker, F.R.S., who dealt with some of the problems of industrial chemistry.

In his reply Lord Crewe, Lord President of the Council, outlined some of the duties and responsibilities of the new department. The following is an extract from the official notice issued at the time (December 1, 1916):—

"The Government have decided to establish a separate Department of Scientific and Industrial Research for Great Britain and Ireland under the Lord President of the Council, with the President of the Board of Education as Vice-President. They have also decided, subject to the consent of Parliament, to place a large sum of money at the disposal of the new department to be used as a fund for the conduct of research for the benefit of the national industries on a co-operative basis."

The sum of money placed at the disposal of the department for co-operative work was 1,000,000*l.*, and is held in trust by the Imperial Trust for the Encouragement of Scientific and Industrial Research, for the work of the industrial research associations referred to in more detail in another section of this address. But in addition the department controls other agencies* and administers further funds devoted to the application of science to industry. The National Physical Laboratory is considered elsewhere. The Geological Survey and Museum is also one of the activities of the department, while under the Fuel Research Board and the Food Investigation Board problems of vital interest are being carried out.

Further work of great importance is dealt with by the co-ordinating boards for chemistry, physical engineering, and radio research, established by the direction of the Government to co-ordinate researches which are of value to the fighting services, and which also have industrial applications. The researches are carried out at the National Physical Laboratory or at other research establishments, usually under Government control, though to some extent university laboratories are made use of. In addition to these there are a number of boards dealing with special problems, the work of one such—the Lubrication Research Committee—is of utmost importance to engineers, and will be referred to again; while finally the department applies a portion of its funds to grants to research workers and students at the universities. The list of aided researches and of publications by individuals in receipt of grants, given in the appendixes to the report, show the wide extent of this branch of its activities and its importance to industry.

Among the many agencies which in recent years have contributed to the application of abstract science to industry the British Engineering Standards Association holds a prominent position.

It was formed in 1901 at the instance of Sir John Wolfe Barry, who until his death held the position of chairman, when six of eight members were nominated by this Institution to investigate the question of steel sections. The organization now numbers some 2,000 members and over 400 committees. It has issued about 170 specifications, covering a wide field. Standardisation is based on accurate measurement, and in the preparation of many of these specifications fundamental principles have been evolved and researches of difficulty and importance have been required.

Another most valuable method of applying science to research is the research laboratory† of a large firm, and though of necessity the work of such a laboratory is aimed mainly at improving the products of the firm, the fact is being realised more and more that for this purpose also investigations into pure science are essential. I need hardly do more than refer to the chemical investigations which have formed the basis of the German dye industry or the researches of Haber and his colleagues on the nitrogen problem—an inquiry advanced here in England by the work of the nitrogen products branch of the Ministry of Munitions.

Perhaps the best known of the engineering research laboratories controlled by an industrial firm is the establishment at Schenectady of the General Electric Company of America. To quote from Dr. Mees' book: "This laboratory is not concerned primarily with the solution of works problems or with investigations on the manufactured products of the company; it has deliberately sought entirely new discoveries, new applications of materials, and new developments in the art of electricity. . . . From it have come the metalized carbon and the drawn-wire tungsten filament lamp, the nitrogen-filled high-efficiency lamp, the magnetite arc lamp, and the Coolidge X-ray tube." The development of each of these has involved investigations of great importance to pure science, and among the workers at the problem, which of all others is now arousing the interest of the physicist, the constitution of the atom, Dr. Langmuir, of the G. E. C. Laboratory, occupies one of the leading places.

The research section of the Westinghouse Electric and Manufacturing Laboratory is organised somewhat differently. It is divided into sections and embraces work from the purely theoretical side of the problems presented to the practical application of principles and problems in the factory.

The laboratory of the Eastman Kodak Company affords another instance of the union between pure science and industry; it is sufficient to refer to the work on light filters which has proceeded from it, and the improvements thereby rendered possible in every branch of photography, and not least in the microphotographic work so important to the engineer.

In England there are few such great laboratories, and for this there are various reasons. In a recent address, in which he stressed the importance of psychology to the worker, Lord Balfour wrote:—"As a nation we have underrated the great work which science can do for industry. We are too apt to think that science is only for men of science and that learning can interest only the learned." The war has taught us another lesson, and the necessity of close co-operation with science is fully realised in every branch of industry. In a publisher's circular recently received, it is stated that:—"Whatever the commodity, if it be of any considerable importance, the factory producing it without the scientific guidance of a closely allied laboratory is working blindfold."

But there were pioneers who recognised this long since. Manganese steel was produced in 1882 from the laboratory of Sir Robert Hadfield, in Sheffield, as the result of a scientific inquiry into the properties of alloys; and many results of high value to science have come from the same source. The foundations of photomicrographic research were laid by Sorby in a Sheffield laboratory, and the Brown-Firth Laboratories of John Brown and Sons have for some time past been engaged under Dr. Hatfield on fundamental researches into the properties of alloys of steel.

In Manchester there are important laboratories attached to the Westinghouse works, and electrical engineers know the value of the researches which go on there. But perhaps I may be permitted to refer in more detail to the work which has recently been begun under my friend and valued colleague, Mr. C. C. Paterson, at the new laboratories of the General Electric Company at Wembley. Many of my audience who were present at the opening ceremony some few weeks back must have gained a new conception of what is meant by a works' laboratory, and of the interdependence of pure science and electrical engineering. Let me quote from Mr. Paterson's own statement of his ideal as given in his account of the laboratory:—

"The question is sometimes asked whether the laboratories undertake 'pure research' or confine themselves to 'applied research.' It is a fundamental assumption that the question is meaningless. If 'applied research' means the application to practical problems of existing scientific knowledge, then it is a misnomer to call it research at all, though the laboratories may have to assist the works in this way. Every practical problem that cannot be solved by the trained experience of a factory superintendent, that is to say, every problem that is likely to come before the laboratories, requires for its solution, not only new information concerning facts, but also some extension of scientific principles. It is the business of the laboratories to provide that extension, and the results are not the less intellectually interesting, because the research for them was dictated originally by some motive other than pure curiosity; nor are the methods by which the search is conducted in any way different from those characteristic of the purest and most academic research."

There is no restriction to the character of the problems attacked or the methods of attacking them except that those problems are naturally taken up which seem to offer the best chance of yielding information of use to those branches of the industry in which the company is or may be interested. When, therefore, the laboratory staff is asked to investigate some manufacturing difficulty, they do not restrict their inquiries to the obvious avenues, but attempt to understand more fully than before the fundamental principles upon which this branch of manufacture is based. The line that the research will follow depends quite as much on the interests of the worker as on the practical problem which provided the starting-point. It has happened already, and will certainly happen again, that a research started in the hope of solving one problem has ended in solving another which was not contemplated in the first instance. Furthermore, because most of the problems arise from the manufacture of electrical appliances, it does not follow that work can be confined to the practice of those branches of science which appear most directly connected with these devices. For instance, lamp research is not confined to work in vacuum physics; it is equally concerned with metallurgical research, glass research, radiation from solids and gases, high-tension electric phenomena, and chemistry—particularly reactions at very high temperatures.

A research laboratory is not complete unless it contains members interested in almost every branch of science, and provides facilities for these and also other classes of work. This wide branching of research, starting originally from an apparently restricted problem, has an incidental advantage; it makes a laboratory which is fitted to undertake one kind of industrial research fitted to undertake all. It is true that there is a certain amount of specialised equipment, such as the laboratory factories, which form part of the organisation, and which are necessary to bridge the gap which separates research from its successful incorporation in factory production. These form a very important part, because failure at this point may render, and often has rendered, useless magnificent efforts on either side of the gap. But they are a small part and, whatever be the needs of the future, the research laboratories can readily direct their efforts to any point from which the new call comes.

These are great aims; a company is to be congratulated which has at its head a man who can make such aims possible, and in its service one who can realize* the ideals with which he has inspired his chiefs.

But laboratories such as this are possible only to the favoured few. In the case of any but the richest firms the cost would clearly be too great. While a works' laboratory in which routine tests are applied to the materials used and products manufactured is a necessity even in the case of small firms, these can only secure the

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* The following figures may be of interest, giving the totals for 14 years:—

Income account.

		l.
Treasury grants to Laboratory	...	80,500
" " for Aeronautics	...	20,182
Receipts for work done ...	...	166,633
Donations	...	15,230
		282,545

Capital account.

		l.
Treasury grant	...	75,941
Private donations	...	55,967
Provided out of income ...	...	24,290
		156,198

† These were Dr. Harker, Mr. Albert Campbell, Dr. Carpenter, Mr. Keeling, Mr. F. E. Smith, Dr. Stanton, Mr. Jakeman and Mr. Melsom.

‡ At the end of the war period the staff numbered some 600.

* Details will be found in the report of the Committee for Scientific and Industrial Research for 1921–22.

† See "The Organisation of Industrial Scientific Research," by Dr. Kenneth Mees, of the Eastman Kodak Research Laboratory.

* In this connection the titles of the following list of Papers already published by the staff are interesting:—

List of Papers on Scientific Subjects by the Research Staff G. E. C.

"Disappearance of Gas in Electric Discharge." Parts 1–3.

"Method for Micro-Analysis of Gas by Pirani, &c."

"High Temperature Phenomena of Tungsten Filaments."

"Disappearance of Gas." Part 4.

"Efficiency of Impurities on Re-crystallization, &c."

"Cathode Disintegration."

"A Problem in Viscosity. The Thickness of Liquid Films formed on Solid Surfaces under Dynamic Conditions."

advantages of pure research by some form of co-operation; and it is to meet this case that the Research Associations of the Department of Scientific and Industrial Research already alluded to have been evolved.

A number of firms concerned in the same industry combine for research purposes. Each contributes its share to the expenses, and the total sum thus raised is met by a grant by the department from the million fund set aside by the Government for this purpose. In most cases the grant is on the pound-for-pound basis, and is guaranteed under certain conditions for five years; there is a limit of 5,000*l.* a year to its amount. The associations are managed by a committee or board, on which the department is represented; each has a Director of Research as its technical officer; the experimental work is carried out either at a central laboratory run by the association or in many cases by arrangement with some suitable institution, *e.g.*, the National Physical Laboratory or the local university.

The results of any research carried out by the association belong as a rule to all the members equally, but a firm may, if the committee approves, have an investigation carried out for its own special benefit at cost price.

Each firm subscribing receives a regular service of summarized technical information and may obtain a translation of any foreign article in which it is interested. It may put technical questions to the committee and recommend specific objects for investigation; these, if approved by the committee, are carried out at the cost of the association for the common benefit of the members. The firm has also the right to use any patents arising from the investigation on the payment at most of a nominal fee.

The number of associations formed up to the present is 24, and among the most interesting to engineers are perhaps the Iron Manufacturers' Association, the Association of British Motor and Allied Manufacturers, the Portland Cement Manufacturers' Association, the Non-Ferrous Metals Association, the Scientific Instrument Association, the Electrical and Allied Industries Research Association, the Cast-Iron Research Association. There is no association to deal with general engineering problems.

The last report of the Department of Scientific and Industrial Research deals at some length with the nature of the researches undertaken by associations; it points out that there is little basic difference between the fundamental research work required by industry and "pure" research, and it states that, while in pure research the phenomena investigated and the inclinations of the worker furnish the only directive forces, in industrial research "the work has a distinct purpose in view, which the investigator must bear in mind constantly. He cannot afford to follow attractive by-paths unless he believes they will lead him to a relevant destination." The outlook is possibly somewhat less wide than that taken by Mr. Paterson—a consequence, no doubt, of the fact that the investigator is working under a board or committee; still the report is able to give some definite examples of the manner in which research into fundamental principles has been required for, and has led to the solution of, an industrial problem.

Thus in one case—not, it is true, an engineering question—three cargoes of apples from Australia valued at from 30,000*l.* to 50,000*l.* were lost from a disease known technically as "brown-heart," said to be due to insect injury in the orchards. Investigation based on a research into the physiology of various foodstuffs proved that the apples had been "suffocated" by the carbonic acid they themselves had produced during the voyage.

Of more direct interest to engineers are the report on alloy steels produced by the Motor Manufacturers' Association, work carried out for the Non-Ferrous Metals Association, and some of the investigations of the Electrical Research Association referred to below. This Association is financed in great measure by the Institution of Electrical Engineers and the British Electrical and Allied Manufacturers' Association, the Councils of which have shown in many ways their appreciation of the interdependence of science and engineering.

(To be continued.)

AGRICULTURAL EXHIBITIONS IN CANADA.—It is the custom in Western Canada to hold during the summer months, at important centres, a series of agricultural exhibitions and fairs. H.M. Trade Commissioners in Canada are of opinion that these afford an excellent opportunity of familiarising traders and consumers in Western Canada with the productions of United Kingdom firms. Arrangements have, accordingly, been made by the Department of Overseas Trade for participation by H.M. Trade Commissioner in Western Canada in the fairs to be held at Brandon, commencing July 2; Edmonton, commencing July 16; Regina, commencing July 30; Vancouver, commencing about the middle of August. At each of these exhibitions a Bureau of Information will be maintained by the Trade Commissioner, at which it is desired to display copies of the leading trade and technical journals of the United Kingdom, particularly those dealing with agricultural and allied matters. The Trade Commissioner proposes not only to display such journals, but to distribute them in suitable quarters, and would therefore be glad to receive up to 50 copies each of journals dealing specifically with agricultural implements and machinery (including stationary engines, tractors, dairy supplies and machinery, grinders, crushers and feed cutters, residential electric lighting plants, &c.), mining, engineering (including wire rope, pulleys, &c.), telephones, mechanics' tools for farm and workshop, municipal equipment, ships' fittings and ship chandlery, and marine engines; and about half that number in the case of other trade journals. Journals may be forwarded directly to H.M. Trade Commissioner at 703, Union Bank Building, Winnipeg.

EXPLOSION OF A BLOW-DOWN PIPE.

A PRELIMINARY inquiry has been made by the Board of Trade, under the provisions of the Boiler Explosions Acts, 1882 and 1890, with regard to the cause and circumstances attending the explosion of a blow-down pipe, which occurred on September 17 last at the Lambton Coke Works, Fencehouses, Durham, owned by the Lambton and Hetton Collieries, Limited, Cathedral-buildings, Dean-street, Newcastle-on-Tyne. Fortunately no one was injured by the explosion. The pipe was made of cast-iron in the form of a right-angled bend. The internal dimeter varied from 3 in. at the top end to $2\frac{1}{2}$ in. at the bottom end, the thickness being $\frac{15}{16}$ in. and $\frac{1}{2}$ in. respectively. The flanges were $8\frac{1}{4}$ in. in diameter and $1\frac{1}{16}$ in. thick at the top end and $6\frac{1}{2}$ in. in diameter and $\frac{7}{8}$ in. thick at the bottom end. They were secured by six $\frac{3}{4}$-in. bolts and four $\frac{5}{8}$-in. bolts, respectively. The inside of the bend was supported by a straight rib $\frac{3}{4}$ in. thick.

The name of the makers of the pipe could not be ascertained. It was fitted in place in 1908, and had been in use for fourteen years at the time of the explosion. During that time no repairs had been made to the pipe. The pipe was insured with the Vulcan Boiler and General Insurance Company, Limited, 67, King-street, Manchester, and was periodically examined by an inspector for that company, the last inspection prior to the explosion having been made on August 12, 1921. It had also been periodically inspected by the foreman fitter at the works, his last examination prior to the explosion having been made on August 15, 1922. The nature of the explosion was such that the pipe fractured completely round the neck below the flange which was attached to the pad on the boiler. After fracturing, the ends sprang apart about $\frac{3}{4}$ in., and through the opening thus formed the contents of the boiler escaped, the pressure at the time being about 80 lb. per square inch.

The explosion was due to fatigue of the material of which the pipe was made, caused by the expansion and contraction of the main range of sludge pipes due to alternate heating and cooling. This movement would cause a cross breaking stress at the neck of the pipe which, continuing over a long period, eventually resulted in the fracture of the pipe under working conditions.

Mr. W. McAustan, Engineer Surveyor to the Board of Trade, in his report, states the pipe which failed was attached to and was used for blowing down a Lancashire boiler known as No. 5, this being one of a battery of six Lancashire boilers used for generating steam for all power purposes at the Lambton Coke Works, at a working pressure of 100 lb. per square inch. The boilers were in continuous use day and night, and were laid off in turn for three days in every six weeks for the purpose of cleaning and examination. No. 5 boiler was last opened out, prior to the explosion, on August 12, 1922. After cleaning it was examined by the foreman fitter at the works. He stated that he carefully examined the blow-down pipe, both visually and by hammer test, and that he saw no sign of any defect. Steam was again raised in the boiler on August 15, and from that date the boiler was continuously under steam until the time of the explosion. During this time the boiler was blown down every night and the pipe appeared to be satisfactory. The blow-down pipe from each boiler joined a main range of pipes which ran at right angles under the boiler-house floor, in front of the boilers to a sump outside the boiler-house. The total length of this range was about 197 ft., and the distance between the centres of the boilers varied from 11 ft. 6 in. between Nos. 1 and 2 to about 29 ft. 6 in. between Nos. 4 and 5 boilers. It was the practice at the works to blow down the boilers every 24 hours; this was generally done on the night shift.

On the night of September 17 the boiler-minder went on duty about 9.40, and shortly afterwards commenced blowing down the boilers. Beginning at No. 1 boiler he blew down each in turn until No. 5 was reached about 10.15 p.m. He had just eased the blow-down valve slightly and was waiting to hear from the fireman stationed at the boiler-house door about seven yards away, whether water was issuing from the main pipe, when the explosion occurred. The force of the explosion displaced the brick work in the vicinity of the blow-down pipe and the contents of the boiler escaped mainly in the direction of the flues. The boiler-minder made his way to the top of the boiler as soon as possible and shut the main stop valve, thereby cutting off the communication with the other boilers and thus minimising the damage. The fires were drawn as quickly as possible, and when the steam and dust were cleared it was found that the blow-down pipe had fractured as described. The arrangement of blow-down pipes in this case was such that no provision was made for relieving the strain due to expansion coming on the bends between the boiler and main range of blow-down pipes. In the case of Nos. 1, 2, 3 and 4 boilers, cast steel bends were fitted, and, Mr. McAustan concludes, "it is now intended to fit a cast steel bend to No. 5 boiler to replace the cast-iron one which failed, also an additional bend of copper between the blow-down valve and the main range of blow-down pipes."

In reviewing this report Mr. Thomas Carlton, Engineer Surveyor-in-Chief to the Board of Trade, in his "Observations," states: "It is not infrequently found that although considerable thought has been given to the design of the boiler itself, but little consideration has been given to the expansive movements of the blow-down ranges of pipes. In a long range of pipes such as this considerable movement of expansion takes place when the pipes are heated, and freedom to move is usually restricted by the boiler blow-down cross connections, which in consequence are heavily strained. In this instance the parts were found to have sprung apart at the fracture no less than $\frac{3}{4}$ in., and it is not surprising that the pipes, being of cast iron, failed in course of time. The adoption of steel for cast iron is a step in the right direction, but flexibility is also desirable."

PHYSIOLOGICAL EFFECT OF HIGH TEMPERATURES AND HUMIDITIES WITH AND WITHOUT AIR MOVEMENT.

THE United States Bureau of Mines have issued a report on this subject. (Serial No. 2464. April, 1923.) By R. R. Sayers (Chief Surgeon, United States Bureau of Mines, Surgeon, United States Public Health Service) and D. Harrington (Supervising Mining Engineer, United States Bureau of Mines). This report, which is a continuation of previous researches by the same authors and already published by the United States Bureau of Mines, gives a further series of results of experiments in this complicated and important subject. In this country the names of Haldane and Hill are particularly associated with the questions involved, and the practical applications of helpful measures in the industries concerned most vitally have aroused the widespread interest which their importance demands. Broadly, one would include the subject under the general heading of ventilation, and the economic value of adequate solution of that problem is well known. For example, output in such trades as laundry work, and dyeing, where the work is carried out in hot or humid atmospheres, shows well-marked seasonal fluctuations, as one would expect. In the great mining industry the bearing of such researches as are here reported strikes one even more forcibly. Under certain conditions output in the limit might be reduced to nil, and actual collapse of the worker can be insidiously produced, opening up the possibility of a train of events, leading directly or indirectly to disaster itself. Still, much has been done to obviate or greatly diminish adverse conditions of the atmosphere of the workers' environment, and progress is being advanced under scientific guidance. To illustrate the disclosures of such researches one need only quote from the terminal paragraphs of this detailed report. It was found that "the untoward effects upon man of almost saturated air with temperature above 90 deg. F. and below 98 deg. F. are much less if the air is moving than when it is still. Further, the output or work that can be done is greater when the air is moving than when it is still, with the above temperature and humidity." "*No beneficial effects* were found by moving saturated air at 98·6 deg. F. or 100 deg. F., even at high velocities, and there was apparently some *disadvantage*." The subject is not new in this country or in America. Much work has been done on it and further research is required before we reach the best solutions of the problems. To those who are following the steps of scientific advance this report will prove a valuable record.

THE INSTITUTION OF AERONAUTICAL ENGINEERS.—The minutes of proceedings of this institution, which have just been issued, contain abstracts of a paper on the constructional design of aeroplanes read in three sections by Mr. C. W. Tinson on October 13 and 27, and on December 1 last, as well as an abstract of a paper by Mr. G. H. Dowty dealing with the design of aeroplane undercarriages of the "Oleo" type. The discussions on the papers are also given in the proceedings, which can be obtained from the Offices of the Institution, at 60, Chancery-lane, London, W.C. 2, at the price of 2*s.* 6*d.*

INSTITUTE OF TRANSPORT.—The Council of the Institute has elected the under-named as officers for the year commencing October 1, 1923:—President: Sir J. G. Broodbank. Past-presidents to serve on council: The Right Hon. Lord Ashfield of Southwell, P.C., Sir Henry P. Maybury, Sir Sam Fay. Vice-presidents: Mr. H. E. Blain, Sir J. E. Eaglesome, Mr. H. H. Gordon, Mr. E. S. Shrapnell-Smith, Sir Herbert Walker, Mr. Arthur Watson. Hon. treasurer: Mr. Philip Burtt. Hon. solicitor: The Right Hon. Sir William Joynson-Hicks, Bart., P.C., M.P. Mr. A. Winter Gray has been appointed secretary of the Institute as from October 1 next, when Mr. H. E. Blain will relinquish the office of honorary secretary and become a vice-president.

THE ROYAL DOCKYARD, COPENHAGEN.—Comments have been somewhat frequent of late on the expenditure at the Royal Dockyard, Copenhagen. Its work is admittedly excellent, but the cost is found to be excessive. A special commission was appointed to look into the matter, and although it has not quite finished its investigations, several possibilities have been considered which might lead to economy. The great drawback appears to be the much too ample space available; there is, in fact, more space than can be turned to useful account. The buildings, also, are spread over far too large an area and communication between them is not satisfactory. The commission has arrived at the conclusion that the only sensible way out of the difficulty would be to scrap the whole of the present dockyard and build a centralised modern establishment in its place. This would incur a very heavy expenditure; the estimates are not completed yet, but there would be a large area of valuable land available for disposal to assist in reducing the cost. Some difficulty exists in the matter of ammunition magazines which the authorities do not want removed any distance, but it is expected that successful efforts will be made to overcome this.

ALTERNATING CURRENT SUPPLY METER.

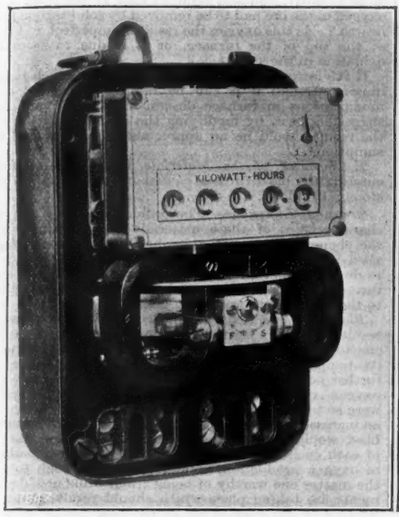

FIG. 1.

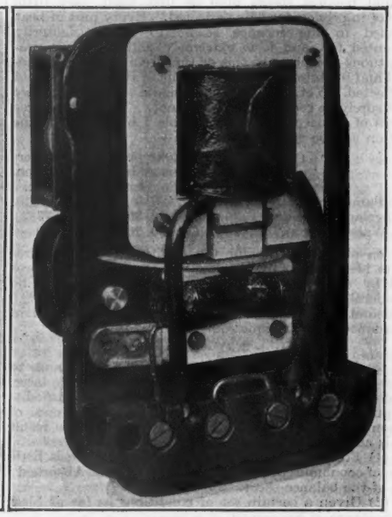

FIG. 2.

A PARTICULARLY neat and compact form of house service meter for single-phase systems has just been placed upon the market by the Electrical Apparatus Company, Limited, Vauxhall Works, South Lambeth-road, London, S.W. 8. The meter, which we illustrate in the accompanying engravings, is of the ordinary induction type and its design does not involve the application of any new principles. There are, however, a number of improvements in its general arrangement and detail design which will doubtless appeal to electric supply undertakings.

The meter is shown in Fig. 1 with the front cover removed, while Fig. 2 is a back view of the working parts completely removed from the casing. The latter is of pressed sheet steel and is made in two parts which are connected by screws at each corner. The screws pass through holes in lugs, the latter being reinforced by pieces of stouter gauge steel plate welded on, as will be seen in Fig. 1. The front cover, of course, contains a glass window through which the dials can be seen, and is also provided with a small auxiliary cover at the bottom giving access to the terminals. The whole of the working parts are mounted on a pressed steel centre plate, which fits into the back cover, and is held in position by two screws. The disc rotor, control magnets and integrating mechanism are mounted on the front of the centre plate as shown in Fig. 1, while the shunt coil and series coils are fixed to the back of the plate above and below the rotor, respectively, as shown in Fig. 2. At the bottom of the latter will be seen a moulded terminal block from which all the connections are made, the centre plate being cut away as shown in Fig. 1 to enable the terminal screws to be reached from the front. It is a simple operation to remove the centre plate from the back cover, together with the working parts, since none of the electrical connections has to be disturbed but this is rarely necessary, since the whole of the adjustments can be effected from the front.

There are several interesting points in connection with the mounting of the rotor. In the first place, the sapphire jewel is carried at the centre of gravity of the rotor and works on a stationary spring-mounted pivot. The jewel is thus above the pivot instead of below it, as is more usual, so that there is no possibility of dirt collecting on the jewel. The spring mounting of the pivot, of course, prevents the possibility of damage to either the pivot or the jewel while the instrument is in transit; both jewel and pivot are easily renewable. The upper end of the rotor spindle is supported by a short steel wire which fits into a hole drilled in the end of the spindle. Excessive lateral movement of the wire is prevented by a small brass barrel which extends downwards from the bearing and surrounds the upper end of the spindle without touching it.

The integrating mechanism, which calls for no particular comment, may be of the clock or cyclometer type, an example of the latter type being fitted to the meter shown in Fig. 1. It is usual to drive the mechanism by a worm mounted on the rotor spindle, but in the meter we are now considering, the worm gear is mounted on the back plate of the clockwork motion, and is driven by a spur wheel which engages with a pinion on the spindle. The worm gear thus runs at a slower speed than would otherwise be the case, and the friction is consequently reduced.

Three adjustments are provided to control the rate, power factor and starting effect of the meter, and all these adjustments can be made by means of an ordinary screwdriver when the front cover is removed. The rate of the meter is varied by means of the screw having an arrow engraved on its head and shown near the centre of Fig. 1, between the control magnets. Turning this screw in either direction moves a rectangular block of soft iron situated in the air gap between the vertical legs of the magnets and so shunts off a greater or lesser proportion of the flux. To adjust for power factor, the rectangular copper loop surrounding the lower end of the central limb of the shunt magnet, as clearly shown in Fig. 2, is raised or lowered by another screw not shown in the illustration. The starting effect is varied by moving the series coils bodily to the left or right, the adjustment being made by means of the screw just visible on the left of Fig. 1. inside the loop formed by one of the control magnets. The series coils are moved until the rotor just starts by the effect of the shunt magnet acting alone, but two small holes drilled through the rotor prevent the latter from turning for more than half a revolution unless some current is flowing in the series coil.

For fixing the meter, screws are provided in the holes shown in Fig. 1 on each side of the terminal block. These screws pass through the back of the casing and are screwed home after the meter has been suspended from the link shown at the top. A leather washer under the head of each screw ensures a dust-tight joint and soft-packing material is, of course, provided in all other joints of the casing. The weight of the meter complete is 4 lb. 11 oz., which is roughly one-third of the weight of a meter of the usual construction, and its overall dimensions are about 6½ in. high, 4¼ in. wide and 3⅞ in. from back to front.

BLAST FURNACE COKE.

*The Reactivity of Coke as a Factor in the Fuel Economy of the Blast Furnace.**

By E. R. SUTCLIFFE and EDGAR C. EVANS.

With a Note by R. V. WHEELER.

THE most authoritative recent British contribution to the study of fuel economy in the iron and steel industry was the report of the British Association Committee presented to the Institute in 1919 by Professor Bone, Sir Robert Hadfield and Mr. Hutchinson.† The section dealing with blast-furnace practice was based to a great extent upon the work of Sir Lowthian Bell and his famous dictum, that "it was useless to hope to smelt a ton of grey iron from the Cleveland stone yielding 41 per cent. of pig metal with anything notably under 20¼ cwts. of coke," was quoted as apparently still representing the practicable minimum of fuel economy. The final conclusion arrived at in connection with blast-furnace economy is summarised as follows: "It would hardly be economical . . . to reduce the coke consumption on the blast furnace below the proportion necessary to provide the minimum number of heat units in the outgoing gases necessary to carry out, in combination with the surplus coke-oven gas, the operations of the plant as a whole without further expenditure of coal either in gas-producers or under boilers."

It is not proposed to deal in this present paper with the last contention, which can only be decided by individual ironworks "after a very careful review of the requirements of the plant as a whole." The following notes deal with the blast-furnace, not as a glorified gas producer, but in its primary function as an apparatus for the reduction of iron ore.

Apparently the general tendency in modern plants is to secure the highest possible economy in the blast-furnace operations, and to instal supplementary plant for additional heat requirements. In the case of new plant this seems the logical method of procedure, if only for the reason that the blast furnace is such an expensive gas producer that the cost of production per British thermal unit of gaseous fuel produced would probably be considered higher than that produced in plant specially designed for the purpose. This question, too, is however outside the scope of this paper. The main question to be dealt with is the limit to which the fuel consumption can be reduced in the actual smelting operation itself.

The eminence of the authorities presenting the above report, and the evident importance attached by them to the work of Bell on the subject, makes it necessary at the outset to review that work in the light of modern knowledge, and to raise the question whether his views regarding fuel economy still represent the last word on the subject.

Bell's Theories on Fuel Consumption.—The opinion quoted above was based on the facts proved experimentally in exhaustive researches, that the indirect reduction of ore ceased at temperatures below 480 deg. C., when the proportion of $CO : CO_2$ in the reducing gas was less than 2 : 1. From this result Bell assumed that once this ratio had been reached in the furnace gases, "the action would be delayed until the mineral reached a level in the furnace, when the heat would resolve any carbon dioxide into carbon monoxide."* If this view be correct, the limiting reaction could be represented by the equation:

$$Fe_2O_3 + 9CO = 2Fe + 3CO_2 + 6CO,$$

which requires, for its solution, a carbon consumption equivalent to 19·35 cwt. per ton of iron produced. After allowing for the carbon required by the iron, the impurities in the coke, &c., this would account for a coke consumption of some 20½ cwt. to 21 cwt.

Whilst Bell tried to extend this hypothesis as widely as possible, he cautiously limited its precise application to the production of No. 3 iron from Cleveland ore (Fe, 41 per cent.) with the use of Durham coke.† It is well known that many furnaces are working with a far lower consumption of fuel and a considerably lower $CO : CO_2$ ratio than is required by the above equation, and it is necessary at the outset to determine the effect of those limitations on the fuel consumption.

The additional carbon required for the manufacture of No. 3 iron can be readily ascertained, as also the fuel required for fluxing the additional slag on Cleveland ore as compared with that of rich ores. These two points are dealt with later, together with the influence of the character of the coke. The immediate point is—does Cleveland ore possess some characteristic which makes it more difficult to reduce than other ores, and which in itself necessitates a higher fuel consumption?

It is well known that some ores are more irreducible than others, and the effect of the physical characteristics of an ore on its ease of reducibility is also well known. Does Cleveland ore possess any special characteristics which make it difficult to reduce? In replying to a contribution by Bell on a paper by Gayley‡ on American blast-furnace practice, the latter referred to some results he had obtained from American ores in comparison with Cleveland and Lancashire ores, showing that Cleveland ore was more easily reducible than high-class American ore, while Wright§ gives the results of experiments on different ores, which indicate that Cleveland ore has, under certain conditions, the highest degree of reducibility.

Apparently then, apart from its low iron content, Cleveland ore does not possess any special characteristics which would *per se* necessitate a higher fuel consumption.

The next question that arises is whether it is possible, under blast-furnace conditions, for a condition of equilibrium to be reached between the ore and the reducing gases which would allow of a definite fixed ratio between the CO and CO_2 being attained. Those gases pass through the furnace with an enormous velocity. Johnson‖ has calculated that the time between the entry of the blast at the bottom of the furnace and its escape from the top in the form of gas may, in modern furnaces, be as short as 2 seconds. Generally speaking, in laboratory experiments, involving reactions between solids and gases, a very considerable time is taken before equilibrium conditions are reached, and it does not seem reasonable to suppose that, in the exceedingly short space of time during which the reducing gases are in the furnace, equilibrium could be attained.

Lastly, if Cleveland ore does not possess any physical characteristics which make it difficult to reduce, how

* Paper read at the meeting of the Iron and Steel Institute, on Thursday, May 10.

† ENGINEERING, vol. cviii, pages 392 *et seq.*

* Journal of the Society of Chemical Industry, 1890, page 709.

† "Chemical Phenomena of Iron Smelting," page 238.

‡ Transactions of the American Institute of Mining Engineers, 1890, vol. xix, page 932.

§ ENGINEERING, vol. cix, pages 631 and 641.

‖ "Principles, Operations and Products of the Blast Furnace," page 117.

can the low fuel consumptions recorded by Bell himself, and by other observers in the case of charcoal and other furnaces, be accounted for. These low consumptions are accompanied invariably by a low CO : CO_2 ratio; and in this connection the extraordinary results obtained by Gayley with dry blast can be cited where the CO : CO_2 ratio fell from 1·7 to 1·25, with a corresponding reduction in fuel consumption of 2,260 lb. to 1,815 lb. These results cannot be accounted for by any theory of equilibrium ratio. It is as well to face the position at the outset, and after allowing to the full for the value of Bell's wonderful pioneer work, there seems to be no valid reason for believing that the fuel economy of a blast furnace is entirely dependent upon reactions taking place in the upper 20 ft. or so. If this be so, Bell's theory falls to the ground; and under suitable conditions the CO : CO_2 ratio, even with Cleveland ore, could be considerably reduced below the "minimum" assigned by Bell, thus allowing of a reduction in fuel consumption.

Interest in this question has been quickened by the remarkable results obtained in modern furnaces within recent years. Howland,* for example, gives detailed particulars of a series of American furnaces all working Mesaba ores, in 20 of which the CO : CO_2 ratio fell below 2·1, and in 16 of which the ratio fell below 1·7. At the same time a revolutionary development has taken place in blast-furnace theory which, if correct, is so radical as to necessitate a complete recasting of the views advanced by Bell.

Johnson's Theories of Blast-Furnace Practice.—In 1905 Johnson† advanced his hypothesis of the "critical temperature" as a controlling factor in Blast-furnace operations. This theory is presented very fully in Johnson's book on blast-furnace practice and need not be restated here. How far this theory has been accepted by British experts is doubtful. Johnson states that it has been rejected in Germany, whilst Potter‡ has shown that it does not hold good for cupola practice. It appears, therefore, to have definite limitations; but, on the other hand, the conception accounts for blast-furnace phenomena in a manner which necessitates its being taken into serious account in any review of blast-furnace theory.

Johnson states that there are two zones of heat generation in a blast furnace: (1) The combustion zone at the hearth, where the carbon is oxidised by the oxygen in the blast to carbon monoxide, and (2) the shaft, where the carbon monoxide thus produced is further oxidised by the oxygen in the ore to carbon dioxide. In so far as the hearth is concerned, it is necessary to attain a certain critical temperature—which Johnson assumes to be the free running temperature of the slag—and certain operations can only be carried out above this temperature, these probably comprising the removal of the last portions of oxygen, the formation and superheating of the cinder, and the melting, carburisation and superheating (above fusion point) of the iron. The difference between the critical temperature and the temperature of combustion determines the "available heat" for these operations. This "available heat" has a pronounced effect upon the fuel economy of the blast furnace. It accounts, for example, according to Johnson, in a quantitative manner for the fuel economies effected by hot blast, and even for the remarkable results obtained by dry-blast. Richards,§ in discussion the saving effected by Gayley with dry-blast, pointed out that the whole of the saving in fuel, which could have been predicted from theory, was only about 3·5 per cent. of the heat value of the coke used, whilst the actual saving was over 19·6 per cent.

Assuming a figure of 2,750 deg. F. for the critical temperature in Gayley's furnace, Johnson calculates that the available heat on the data supplied was 1,090 B.Th.U. and 1,420 B.Th.U. per pound of fuel with moist and dry-blast respectively. The coke consumption before the change was 2,140 lb., afterwards it was 1,700 lb.; whilst if it were in inverse proportion to the available heats it would be 1,640 lb. The difference between the practical result and the theoretical calculation is so small that the conception of "available heat," or rather of "hearth heat," as it is now called, is one that merits detailed attention.‖

The CO : CO_2 ratio, according to Johnson's conception, becomes a matter not of definite established chemical equilibrium, but of simple arithmetic. Each unit of iron requires for its final reduction and melting in the hearth a definite quantity of hearth heat. To produce this, a definite quantity of fuel must be burnt to carbon monoxide. A proportion is oxidised by the oxygen in the ore to produce carbon dioxide, resulting in a final mixture of these gases in a proportion depending entirely upon chemical arithmetic.¶

It is evident that this theory differs radically from Bell's. Bell's "cause" of fuel consumption—the chemical equilibrium between carbon monoxide, carbon dioxide, and ore in the upper region of the furnace, depending on the CO : CO_2 ratio—becomes with Johnson an "effect," governed entirely by the carbon consumption required to produce the necessary hearth heat. Whether the theory be one which will stand the test of time in every detail or not, it is one which lends valuable help in attacking some of the more obscure problems in blast-furnace technology and opens up very interesting possibilities of reducing fuel consumption, particularly in the direction of increasing the hearth heat. Before proceeding, however, it might be advisable to touch very briefly on the present general aspects of blast-furnace practice in England.

The British Blast Furnace.—A most valuable analysis of British blast-furnace practice was given by Clements in 1920.* The accurate and detailed chemical and thermal balance sheets give at first sight very little hope of improvement being effected. Every unit of heat supplied to the furnace seems to be satisfactorily accounted for, and it is extremely difficult—even presumptuous—to point to this or that item on the balance-sheet and to state definitely that this or that saving could be effected. Yet, from a purely general standpoint, there must surely be room for improvement. Taking the three groups of furnaces detailed in Table I by Clements, the position can be summarised thus:—

	Pig-Iron Yield. Per Cent.	Coke per Ton of Iron. Per Cent.	Carbon per Ton of Iron. Per Cent.
Midland section...	30	29·0	23·4
Cleveland section	35	22·36	18·77
S. Wales section...	48	20·26	16·19

Even after allowing for the additional heat requirements necessitated by the low iron content of the ores used by the Midland section, there would seem to be considerable scope for reduction in fuel consumption.

Theoretically, if pure iron ore could be reduced in accordance with the equation—

$$Fe_2O_3 + 3CO = Fe + 3CO_2$$

the total carbon requirements would only amount to 6¼ cwt. per ton of pig-iron, whilst, as will be shown later, the chemical and thermal requirements can be satisfied—for pure ore—with an expenditure of only 8·6 cwt. of carbon per ton of pig-iron. Mr. Clements, as the result of his analysis, came to the conclusion that:—

"(1) For a furnace built on good lines there is little hope of economies being effected on the 'Heat Absorbed' side of the balance-sheet.

"(2) Given a certain set of conditions as far as blast temperature is concerned, the economy in carbon consumption depends entirely upon the proportion burnt to carbon dioxide."

In other words, we are back again at the CO : CO_2 ratio!

In this connection, however, it must be pointed out that the production of a higher proportion of carbon dioxide will not only involve a lower carbon consumption on the "Heat Produced" side of the balance-sheet, but will also effect economies on the "Heat Absorbed" side, chiefly in the following directions:—

A. The item "sensible heat in exit gases" would be reduced, owing to the smaller quantity of blast that would be required to burn the smaller quantity of carbon.

B. The reduced carbon consumption would require less coke, and less slag (from this coke) would be produced. The "heat in molten slag" would therefore be reduced.

C. Arguing from results obtained in cases where fuel economies have been effected by the introduction of hot-blast, dry-blast, &c., radiation and other losses per unit of iron would be reduced.

In other words, fuel economy is cumulative in character and affects both sides of the "thermal balance-sheet," with practical results that are generally considerably greater than those which would be deduced simply from a consideration of the "heat produced" side. Any method, therefore, which can result in an increase in the proportion of carbon dioxide is one which is worthy of very serious attention on the part of the blast-furnace manager.

When it comes to specific suggestions as to how this can be effected, so many factors are involved that it is extremely difficult to cover them even in a general way. This is especially true where the question is dealt with by investigators who are not engaged in the industry itself.

The influences which determine an increase in the carbon dioxide percentage in blast-furnace gas can perhaps be summarised as follows:—

1. *Blast-Furnace Design.*—This question in its general aspects is outside the province of this paper. There is, however, one point of a theoretical character which can be mentioned, as it raises in the mind of an outsider to the industry the question whether the blast-furnace in its present general form is an ideal instrument for the smelting of iron.

The influence of furnace design on fuel economy was recently treated by Reese† in another paper. Whiting‡ quoted the case of two furnaces using the same ores, fuels and fluxes, but varying in shape, size and rate of driving. In one case the fuel consumption was 12·8 cwt. of carbon per ton of iron with a CO : CO_2 ratio of 1·5; in the other it was 14·9 cwt. of carbon per ton of iron with a ratio of 2·38. At the close of his paper a very interesting statement is made to which it is worth drawing attention. In the operation of the more efficient furnace a change was made from a burden containing all ore to one containing a large proportion of scrap. In the latter case it was found necessary to have an excess of coke (after satisfying the requirements of the ore), so that 1 lb. of coke dealt with 3·2 lb. of scrap.

In the ordinary cupola 1 lb. of coke will melt 10 lb. of scrap—why, therefore, was this great excess required in the blast furnace? Whiting considered that the reason was that reoxidisation of the iron took place by carbon dioxide in its passage down the furnace. Figures on this point from British furnaces would be of considerable interest, but if this result be representative of ordinary practice, it raises a very important question as to the means that could be adopted in minimising or reducing such secondary reactions.

Bell's earlier view was that the bulk of the oxygen in the ore was removed in the first 20 ft. of its descent in the furnace. By 1890, however, he had come to the conclusion that about 25 per cent. of the oxygen remained in the ore in the form of a suboxide and was not removed until it reached the vicinity of the tuyeres.* More recently, Johnson assumed that 10 per cent. of the oxygen in the ore had to be removed by solid carbon in the hearth.† Is this oxygen the result of imperfect reduction at the top of the furnace, or is it due to secondary oxidation in the shaft?

If the latter, it results in a thermal loss which may be important, and if it can be reduced either by slight modifications in furnace design, or alternatively, as is suggested later, by modifying the character of the fuel, the result should be an appreciable saving in fuel consumption.

2. *Character of the Materials Used.*—The materials entering the blast furnace consist of: (1) Ore; (2) limestone; (3) blast; (4) coke.

Ore and Limestone.—The influence of the physical characteristics of these materials—apart entirely from the chemical characteristics—has recently been emphasised by Mr. Reese, and there is no need in this paper to do more than once again point out the effect of structure, particularly of the ore, in increasing its "reactivity to the action of the reducing gases."

Blast.—It is a remarkable fact that the most notable results in the direction of fuel economy have been effected by treating the blast, especially by increasing its temperature and by its dehydration. There is a further possibility now opening out in the increase of its oxygen content. The results obtained by dry-blast were so important as to lead the authors to believe that an increase of but 5 per cent. in the oxygen content of the blast would be attended by marked results. The cost of each such enrichment, even under present conditions of oxygen production, should not be too high to make the matter one worthy of being tried, while new developments are taking place which should result in the production of oxygenated air in the near future at a cost low enough to bring it within reach of practically every furnace. If Johnson's theory be sound, the theoretical possibilities of an increase of 5 per cent. of oxygen in the blast are sufficiently attractive to make the matter one worthy of trial.

Fuel.—Modern theory places the critical zone of the blast furnace, in so far as fuel economy is concerned, at the hearth, where the principal reactions take place between the oxygen and the fuel. Blast-furnace men rightly attach considerable importance to the character of the fuel used, and as the result of generations of experience have been led to demand special qualities in the coke supplied to them. Before proceeding to discuss these, it might be advisable to mention the twofold functions of a blast-furnace fuel. It has to supply (1) the heat necessary to satisfy the thermal requirements of the furnace, and it has (2) to supply the carbon necessary for the reduction of the ore. Both combustion and reduction are chemical processes, and it might have been anticipated that in the length of time during which the blast furnace has been in use that a tendency would have evinced itself in the direction of securing in the fuel a property which is now being recognised as one of the most important in chemical operations where solids are used—the property of "reactivity." There does not, however, appear to be any pronounced demand in this direction, and the principal qualities asked for to-day by British workers appear to be those sought forty years ago.

The most recent statement of the essentials of a good blast-furnace coke is that of Mr. Reese, and the following summary of his requirements can probably be taken as representing modern British views on the subject.

Essentials of a Blast-Furnace Coke.

1. Freedom from ash and sulphur.
2. High carbon content.
3. Resistance to the action of CO_2 in the upper region of the furnace.
4. Rapidity of combustion. To secure this, the size of the coke lumps must not be too great.
5. Uniformity of size. A maximum size of 4 in. to 6 in., and, on the other hand, freedom from smalls.
6. Strength without "density," as "density" is inimical to rapid combustion and fast driving.
7. Porosity—or highly developed cellular structure—which, however, must not be so open as to reduce strength, with the subsequent production of smalls.
8. Hardness—to resist abrasion in the furnace.

The above summary introduces some requirements which were not generally recognised in Bell's time, when the principal requisites of a fuel were: (1) Low sulphur; (2) resistance to CO_2; (3) strength; and (4) hardness. A coke was preferred which was silvery grey in colour and "rang" when struck with a hammer. The demand for a pronounced cellular structure and for rapidity of combustion is a more or less modern development, and in this portion of the specification there is a tentative move in the direction of a "reactive" fuel.

Taking the above requirements in detail, some of the qualities asked for are of a character which are above criticism. The necessity, for example, of a low sulphur and ash content is admitted by all, and recent innovations in cleaning coal offer possibilities of supplying a coke of a degree of purity that, except in special cases, has not hitherto been obtainable. In so far as the third requirement is concerned, resistance of the coke to solubility in carbon dioxide, the authors venture to propound the heresy that this quality, far from being detrimental, is actually one of the most valuable that a coke can possess. The question, however, is dealt with in detail later on.

Physical Properties of Coke.—Apart from the porosity,

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* Transactions of the American Institute of Mining Engineers, 1917, vol. lvi, page 339.

† *Ibid.*, 1905, vol. xxxvi, page 454.

‡ Transactions of the Eighth International Congress of Applied Chemistry, 1912, Section 111A, page 135.

§ Transactions of the American Institute of Mining Engineers, 1905, vol. xxxvi, page 745.

‖ *Cf.* J. E. Johnson, "Principles, &c.," page 33 *et seq.*

¶ Johnson, *op. cit.*, page 151.

* ENGINEERING, vol. cix, page 646 *et seq.*

† ENGINEERING, vol. cxiv, pages 303, 312.

‡ Transactions of the American Institute of Mining Engineers, 1891, vol. xx, page 281.

* Journal of the Iron and Steel Institute, 1891.

† J. E. Johnson, *op. cit.*, page 79.

cellular structure, and size of the coke charged, qualities closely related to its combustibility and therefore dealt with later, the principal qualities required in a blast-furnace coke are strength, to withstand the weight of the burden, and hardness, so that the coke may suffer as little abrasion as possible during its passage through the furnace. The authors do not wish to minimise the importance of a sufficient degree of strength and hardness in a coke to prevent its being ground up in a furnace. A careful analysis of the position raises, however, the question whether these qualities are so desirable as have hitherto been supposed. A remarkable paper on this subject was read as far back as 1879 by Professor Church,* dealing chiefly with the relative qualities of coke, anthracite, and charcoal as blast-furnace fuels. Some of the points raised in that paper are touched upon later, but in referring to the qualities of strength, &c., required, the author remarks: "Blast-furnace managers require coke, hard, strong, and ringing—in fact, they want every quality that charcoal does not possess; perhaps by making a lighter article, avoiding high heats in coking, and aiming to produce a porous delicate coke, it might be possible for a coke furnace to draw nearer her charcoal sister in economy of fuel."

As the result of his studies, Church ventured at the close of his paper to raise the question whether the objection to a "weak" fuel on the part of the blast-furnace manager was not a chimera, and whether it would not be better to sacrifice some proportion at any rate of the "strength" of coke with a view to securing a higher degree of combustibility.

The objections to a weak coke are well known, but if a coke is strong enough to withstand the burden and to resist excessive abrasion, that is all that is required, and if by the sacrifice of a proportion of these qualities a higher degree of combustibility can be gained, it will be to the advantage in securing a greater fuel economy in the furnace.

Solubility of Coke in Carbon Dioxide.—There is hardly any quality in coke which has been more strongly condemned than that of its solubility in carbon dioxide. Every writer on the blast-furnace from Bell to Johnson, every fuel technologist, and every coke-maker, has almost unanimously recorded his opinion that this action is one of the most deleterious to fuel economy that can be experienced. This conclusion has been arrived at on practical as well as theoretical grounds, and has been supported on the laboratory side. Bell made a number of experiments. He showed that soft coke was affected at 427 deg. C., whilst good hard coke was not acted on until a temperature of 815 deg. C. was attained. Further, the relative solubilities of hard and soft coke in carbon dioxide at 800 deg. C. were in the ratio of 1 : 2.

On the practical side Bell quotes a test† in which soft coke was tried in a blast-furnace with the result that the carbon dioxide in the furnace gases showed a considerable diminution for some time. This test, however, does not appear to be a very conclusive one. A much more exhaustive test‡ was made at the Clarence Works with a large batch of soft coke made after lighting up some new ovens. "The quantity of carbon dioxide found in the gases, per ton of iron made, fell considerably, and the consumption of coke rose in proportion." Bell extended the view relating to solution of carbon by carbon dioxide to the direct action of carbon upon the ore. The action results in a loss of heat owing to the endothermic character of the reaction. Bell showed that the power of carbon to act on oxide of iron was modified by its physical condition, charcoal, for example, being much more active than coke. His views as to loss of heat by solution were afterwards confirmed by Fulton.§ Investigating the reasons for the marked inferiority of Johnstown coke as compared with Connesville coke in the blast-furnace, Fulton came to the opinion that the results obtained were due to "softness of body" in the Johnstown coke causing it to be ignited in the upper regions of the furnace, not only wasting its heat there, but disarranging the operations of the furnace. Fulton's conclusions were based upon laboratory experiments only.

The laboratory and practical experiments made by the above authorities are supported to some extent by the inferior results obtained by blast-furnace managers when soft coke is used, and, generally speaking, the high fuel consumptions recorded in such cases are attributed to high solution losses. On the theoretical side likewise there is a very considerable weight of expert opinion in favour of the view that solution loss is a very serious factor in high fuel consumption. Gruner, for example, in 1879 propounded his well-known theory that the condition of ideal working required the fuel burnt by the blast at the tuyeres to be a maximum and that dissolved by the oxygen of the charge a minimum; in other words, solution loss in the upper region of the furnace, whether occasioned by carbon dioxide or by the oxygen in the ore, is a cause of increased consumption of fuel.

That view is emphasised by Johnson,‖ both on theoretical and practical grounds. Johnson found in working a charcoal furnace on rich ores that when the departure from Gruner's ideal working is considerable, as shown by the small quantity of blast required to burn a pound of fuel, the fuel economy is poor, and when the quantity of blast to burn a pound of fuel goes up, the fuel economy increases in the same proportion, in exact accordance with Gruner's theorem. On the theoretical side Johnson devotes the whole of Chapter V. of his work to a consideration of the thermal effects of loss of fuel by solution. In a series of detailed and careful calculations he demonstrates the effect of solution losses under varying conditions in the blast-furnace, his work thus lending powerful support to the popular view that a coke of high solubility is an inferior one for blast-furnace purposes.

Taking a general view of the question, it seems at first sight a thankless task to challenge the formidable body of expert opinion outlined in the above summary, and to venture to propound the theory that a high solubility factor is an advantage in a coke. Yet, if a careful analysis be made of the evidence on which this opinion is based, it does not seem so overwhelming as it appears at first sight, whilst, on the other hand, arguments can be advanced, and calculations put forward, which offer very strong support to the view that high solubility is an extremely desirable factor in a coke.

At the outset laboratory results show that soft coke is more readily acted upon by carbon dioxide and the oxygen in the ore than hard coke; this had been confirmed by every known investigation on the subject. The reasoning, however, that this effect is deleterious in the furnace is not so conclusive. The results obtained by Bell, and confirmed by blast-furnace managers in general, as to the deleterious effects of soft coke, do not seem to afford very strong ground for the opinion that this is due to solution losses. The authors consider that the low carbon dioxide results obtained by Bell were due, not to solution loss, but to the physical action of the coke in the furnace. As a matter of fact, Bell himself supplies an explanation in this direction. In discussing the relative advantages of anthracite, coke, and charcoal in the furnace, he considers* that the main disadvantage of anthracite lies in the fact that it "has a tendency to splinter, thereby blocking up the air passages, and interfering with the proper access of the reducing gas to the ore."

This the authors consider is the reason for the poor results obtained with soft coke in the past. Under existing conditions of carbonisation, any soft coke produced is actually and not relatively "soft." Such coke as "black ends" and soft coke made at low temperatures in existing coke-oven plants is not nearly strong enough to stand the burden in the furnace without being crushed more or less to powder. This in itself would result in channelling, and in an uneven distribution of the reducing gases, with a consequent inability to act completely on the ore. There is therefore quite as much reason to attribute the deleterious results obtained with soft coke to purely physical causes as to the chemical effects of solution.

In so far as Fulton's results are concerned, the evidence advanced by him does not seem in any way to be conclusive, whilst his laboratory results were criticised by Dewey.† The authors therefore do not think it necessary to review this work in detail. Johnson's views, however, demand much more serious attention. It is impossible to discuss the practical work quoted by him without fuller knowledge of the conditions involved, but his theoretical calculations demand extremely careful attention. At first sight his views and assumptions seem convincing. Briefly, his opinion can be expressed as follows:—

The amount of oxygen that can be imparted to the fuel in the hearth is limited by the fact that the only oxide which can exist under the temperature conditions therein is carbon monoxide. In order to convert this into CO_2 the only oxygen available is that from the ore; therefore, if any fuel is dissolved in the upper part of the furnace, a corresponding amount of oxygen is lost at the hearth, which deficiency can never be made up, and represents a net loss of heat development when the gas is discharged from the stack.‡

If this theory be correct, a solution loss of coke in the furnace, apart from its attendant thermal loss, would result in a very serious loss of fuel.

It is important to note that Johnson's calculations are based entirely upon the "critical temperature" theory. It is difficult to criticise them without knowing how far the accuracy of that hypothesis extends, and the simplest method of testing the truth of those theories would be to consider the practical results recorded in blast-furnace practice from two standpoints, viz.: (1) to note the influence of fuels of high solubility on fuel consumption, and (2) to determine whether high solution loss is generally associated in furnace practice with high fuel consumption.

Influence of Fuels of High Solubility on Carbon Consumption in the Blast-furnace.—A considerable amount of work has been performed on the relative solubility of different fuels in carbon dioxide. Bell,§ for example, quotes the results given in the next column.

Similar results have been obtained with regard to the comparative power of different fuels in the direct reduction of ore by solid carbon. Invariably it has been found that the relative solubilities of the three blast-furnace fuels in general use are in the following order:—(1) Charcoal; (2) coke; (3) anthracite. If, then, solubility be such a deleterious factor, it might reasonably be expected that the relative efficiencies of these fuels would be in the order: (a) Anthracite; (b) coke; (c) charcoal. Instead of this, however, charcoal in a blast-furnace invariably gives better results than coke, and coke than anthracite.

Action of Carbon Dioxide on Different Fuels at Red Heat.

Composition of Issuing Gases.	Hard Coke.	Soft Coke.	Charcoal.
Carbon dioxide, per cent.	94·56	69·81	35·2
Carbon monoxide, per cent.	5·44	30·19	64·8

Action of Carbon Dioxide and Coke at Different Temperatures.

	Temperature.	Percentage of CO in Issuing Gas.
Charcoal ...	319 deg. C.	0·0
„ ...	393 deg. C.	0·4
„ ...	918 deg. C.	13·0
Durham Coke...	332 deg. C.	0·0
„ ...	485 deg. C.	0·3
„ ...	906 deg. C.	2·5

How can the superiority of charcoal as a furnace fuel be accounted for in the face of its much higher solubility? Bell's suggestion is ingenious. He states that previous ignition of both coke and charcoal greatly lessened their action on CO_2, and he advances the suggestion that "it may fairly be considered whether, after charcoal has been exposed to previous ignition in the blast-furnace . . . . there is any difference between coke and charcoal in their power to resist carbon dioxide. Indeed, it seems possible that at the higher temperatures which obtain in smelting iron, charcoal may be rendered less liable to attack from carbon dioxide than coke is."*

The authors have no hesitation in joining issue with that statement. In the blast-furnace the temperature rise is a gradual one, so that the charcoal or coke is only slowly heated to its maximum temperature. The authors have found that if coal be heated in this way, so that the temperature be only slowly increased, the coke produced is very active and possesses a high degree of combustibility and therefore of solubility in CO_2. Further, in a blast-furnace the coke or charcoal is being heated in a stream of inert gas of constantly increasing temperature. It has been found that coal heated in this way under suitable conditions becomes converted into an activated carbon possessing an extremely high power of absorbing vapours, and with a combustibility and solubility greater than that of any blast-furnace charcoal yet produced.

Another suggestion that has been advanced is that of Foster,† that the solubility of charcoal in carbon dioxide is reduced owing to the occluded or condensed gases that it contains. This ingenious suggestion, however, does not accord with the result of experiments made with activated carbon. The capacity of this material for retaining condensed gases or vapours is considerably greater than that of ordinary charcoal. It will, for example, remove benzol completely from coal gas, and will retain this material at temperatures considerably over its boiling point. By passing steam or other inert gas over the carbon at 300 deg. C., the whole of the condensed vapour can, however, be quite readily removed.

In the case of the blast-furnace, the charcoal which enters is being subjected to the action of a constant stream of inert gas of continually rising temperature, and in all probability before the charcoal reaches the zone where solution is effected, the condensed or occluded gases will have been removed and replaced by a mixture approximating in composition to the furnace gas.

Rhead and Wheeler failed to note any evidence of the condensation or occlusion of gas in charcoal heated at 400 deg. C., and observed that the reactivity of the charcoal towards oxygen was enormously increased by previous heating at a high temperature.‡ Professor Wheeler suggests that there is no reason why preliminary heating of charcoal should not, in a similar manner, increase the reactivity of the charcoal towards carbon dioxide; that is to say, he is in direct disagreement with Bell and with Ackerman as to the preliminary heating conferring on charcoal a power of resistance to the action of carbon dioxide.§

The weight of evidence is all against the view that charcoal is protected against the action of carbon dioxide in any way whatever. This action must take place. How, then, can the low fuel consumption in charcoal furnaces be accounted for?

The question can perhaps be best answered after considering results recently obtained with modern coke furnaces working in many cases with very low fuel consumption.

(To be continued).

THE DANISH STATE RAILWAYS.—The report for the last financial year has been stated to be the most unsatisfactory in the history of the railways. The receipts amounted to 170,800,000 kronen, and expenditure to 233,200,000 kronen, resulting in a deficit of 62,400,000 kronen. This unsatisfactory result is partly owing to a decline in the receipts due to the general industrial depression, and partly to the fact that expenses could not be materially reduced, the service having been extended. In addition, 16,100,000 kronen were written off the railway stocks of dear coal. The aggregate length of the Danish State Railways at the end of the financial year was 2,409·66 km. and the cost of construction 4,77700 794 kronen. The number of permanent employees was 19,533 and of casual workmen 3,100. Of passengers, 2 were killed and 18 injured, the figures for the employees being 6 killed and 581 injured.

* Transactions of the American Institute of Mining Engineers, 1878, vol. vii, p. 33.
† "Principles of the Manufacture of Iron and Steel," p. 102.
‡ *Ibid.*, p. 196.
§ Transactions of the American Institute of Mining Engineers, 1883, vol. xii., p. 212.
‖ J. E. Johnson, *op. cit.*, p. 75.

* "Principles of the Manufacture of Iron and Steel," p. 290.
† Transactions of the American Institute of Mining Engineers, 1883, vol. xii, p. 111
‡ Apparently, then, this reasoning would imply that the greater the blast per lb. of carbon used, the greater the economy of the furnace.—Author's note.
§ *Op. cit.*, p. 287.

* *Op cit.*, p. 289.
† Journal of the Iron and Steel Institute, 1904, No. 1, p. 320.
‡ Transactions of the Chemical Society, 1913, vol. ciii., p. 467.
§ This statement is from a private communication from Professor Wheeler to the authors.

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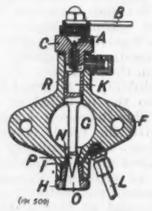
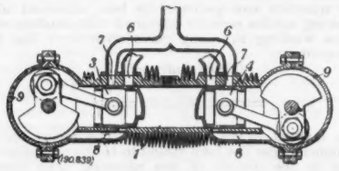
GAS ENGINES, PRODUCERS, HOLDERS, &c.

191,509. A. Forman, Beattock, and R. Matchett, Beattock. Internal-Combustion Engines. (2 *Figs.*) October 25, 1921.—The invention relates to apparatus for supplying humidified air to the combustible mixture of internal-combustion engines. According to the invention, the water is admitted through an annular adjustable orifice or annular adjustable water space I at the throat of a Venturi tube or double conical passage N, O, through which air alone is induced with the water, the passage of air through the tube or passage N, O, and consequent water supply, being controlled by a valve P actuated entirely by suction and located in the throat or narrowest portion of the tube or passage N, O. F is a flanged body or casing that is fixed between the carburettor and induction pipe of the engine and has a central passage G which forms part of the induction passage. The passage N, O opens into the passage G; the portion O is formed in an adjustable plug H screwed into the casing F in such manner as to form the annular orifice or water space I to which water is supplied by a water pipe L. The valve P is carried by the stem of a piston K which is of larger diameter than the valve P, and is



a loose fit in a cylindrical chamber R. C is a plug screwed into the casing F and A is a rotary conical valve fitted in the plug C. The valve A has an air hole which may register with an air hole in the plug C. The valve A is turned by a lever B. The operation of the apparatus is as follows: When the valve A is turned so as to bring the air hole therein into alignment with that in the plug C and the engine is at rest, the atmospheric pressure will act equally on both the upper and lower surfaces of the piston K, so that the valve will be free to move. If the engine is started, the reduction of pressure in the induction passage G causes the pressure on one side of the piston K to be less than the atmospheric pressure in the chamber R acting on the other side of the piston K. Consequently, the valve P is held closed. After starting-up the engine, the valve A is turned to bring the air hole therein out of alignment with that in the plug C and the engine suction in the passage G partially exhausts the chamber R and causes the atmospheric pressure on the valve P to lift or open the valve. The engine suction then induces additional air through the air inlet O, thus atomising water drawn from the space I so long as the valve P is raised. (*Sealed.*)

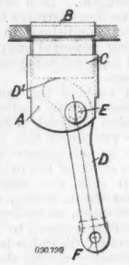
190,839. H. Leigh, New Mills, and S. Hobson, New Mills. Internal-Combustion Engines. (2 *Figs.*) October 15, 1921.—The invention relates to that kind of internal-combustion engine wherein two pistons are arranged to reciprocate in opposite directions in a cylinder which, with the two pistons, forms a common combustion chamber. An internal-combustion engine of the specified kind, and as constructed in accordance with the invention, comprises a working cylinder 1 containing two pistons 3, 4, both simultaneously performing their working strokes and



forming with the cylinder a common combustion chamber. A closed crank-case 9 is arranged at each end, while two separate transfer ports 8, one at each end, are connected to a different crank-case. Two separate inlet ports to the combustion chamber are arranged at opposite sides of the middle of the cylinder, each connected to one of the transfer ports, while two exhaust ports 6 are placed substantially diametrically opposite the said inlet ports, and two ports 7 in the cylinder further towards the ends thereof for the introduction of working mixture into both crank cases 9 of the engine. (*Sealed.*)

LIFTING AND HAULING APPLIANCES.

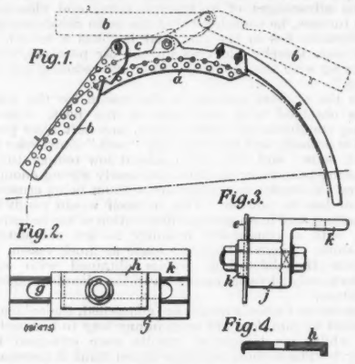
190,796. J. S. Hill, Glenboig. Haulage Clips. (4 *Figs.*) September 28, 1921.—The invention relates to haulage clips. A haulage clip, according to the invention, comprises a boxlike casing A open at either end and with an extension B forming a hood or canopy. A block C grooved in the centre for the reception of the haulage rope is loosely carried in the boxlike casing A. D is a lever pivoted to the boxlike casing A at E, and F is the eye at the lower end of the lever D for connecting to the hutch. When the clip is attached to the haulage rope, the rope lies under the canopy B and the chain at the end of the lever D is attached to the hutch. When the chain is in tension or taut, the movement of the lever D causes its rounded head D^1 to act on and raise the block, when it presses the rope hard up against the underside of



the canopy B and thereby effects a tight grip or hold on the rope. When the tension is taken off the chain, the block C falls and the grip or hold on the rope becomes automatically released. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

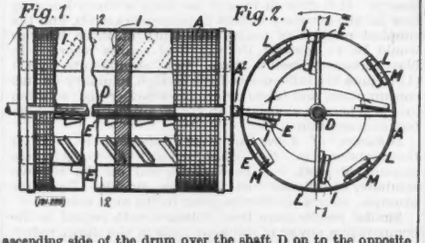
191,475. W. G. Cook, Sheffield. Guards for Circular Saws. (4 *Figs.*) October 13, 1921.—A guard for a circular saw comprises a stationary hood or guard *a* held by and connected to an arm (not shown) adjustably held by a standard and a second hood or guard member *b* pivotally connected to the stationary hood *a* by a link or links *c* and capable of being locked in position over the saw or turned back out of use, both hoods being of thin sheet metal or of woven wire or metal gauze of U cross-section and



preferably perforated. For clamping the lower end of the riving knife *e* an L-shaped bracket *k* is bolted to the underside of the bench, the vertical portion of which has a longitudinal slot *g*. A clamping plate *h*, provided at one end with a flange and at the other end with a claw-like flange, is adjustably secured to the bracket *k* by means of a bolt passing through the slot *g*, the riving knife *e* being held firmly between the clamping plate *h* and a wood spacing piece *j*. (*Sealed.*)

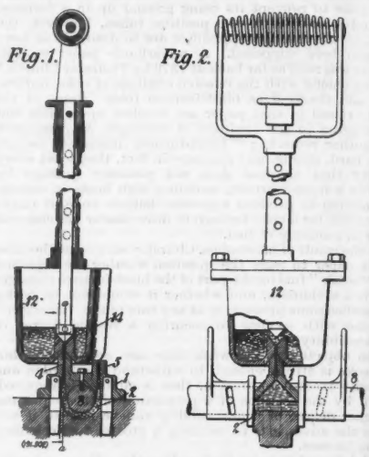
MINING, METALLURGY AND METAL WORKING.

191,269. N. Harrison, Low Fell. Screening Apparatus. (2 *Figs.*) December 21, 1921.—The invention relates to screening apparatus of the kind comprising a rotary screening drum A of perforated plating or mesh, provided internally with longitudinal lifting plates projecting inwards from the inner periphery of the drum, the material being fed into the drum at one end and transferred through it for screening to the opposite end with the aid of propelling members disposed inside the drum. According to the invention, there is mounted inside the drum A at intervals a number of detachable and adjustable vanes or plates E, which project from the inner periphery of the drum tangentially and at such an angle to the axis of the drum that an extension of their upper surfaces would pass over the shaft D of the drum, these plates being arranged to lift the material and project it from the



ascending side of the drum over the shaft D on to the opposite side of the drum for sifting, the propelling of the material through the drum being effected by means of propelling plates I arranged at a suitable angle above the lifting plates. In addition to the lifting and propelling plates, members L of similar construction may be arranged around the inner periphery of the drum at an angle to the direction of rotation and secured in such manner as to leave a space M between their outer faces or the outer faces of their supporting plates and the inner surface of the drum, the spaces M increasing in size in the several sections of the drum towards the discharge end A^2 of the latter in accordance with the increasing size of the interstices of the plating or mesh in different sections of the drum, so that the spaces will pass only material of the size of the perforations which it is desired to screen at the particular section of the drum. (*Sealed.*)

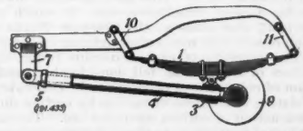
191,502. A. D. Powell, Bocking, Braintree, and Lake and Elliot, Limited, Braintree. Casting Bearing Metal.—(7 *Figs.*) October 19, 1921.—The invention relates to apparatus for casting bearing metal. According to the invention, the apparatus comprises a mould 1 adapted to be positioned on the work and associated with means for forming the core of the bearing, the mould being provided with a runner port 4 adapted to co-operate with a ladle 12 and with a vent port 5 communicating directly with the mould space, the vent port 5 being provided with means whereby the molten metal passing into the vent is prevented from flowing out by providing for the metal to be chilled therein. The invention also consists in the provision of apparatus comprising a mould 1 or a number of moulds adapted to be detachable and adjustably secured to a core rod 8, a runner port 4 on one side and a vent



port 5 on the opposite side of each mould, each runner port 4 being shaped to co-operate with, and form metal tight contact with, the pouring orifice 14 of a ladle or container 12. Each vent port 5 communicates with the mould space 2 and is tapered to form a restricted opening, thus causing the molten metal which passes into the vent port 5 to chill and prevent the outflow of molten metal through the restricted opening, and allow casting metal to press into the mould space 2 due to the weight of the molten metal in the ladle or container 12. (*Sealed.*)

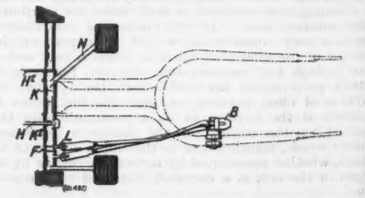
MOTOR ROAD VEHICLES.

191,433. T. W. E. Brogden, Dungannon, County Tyrone. Springing of Road Vehicles. (7 *Figs.*) September 15, 1921.—The invention has reference to leaf spring suspension systems in which means are provided for varying the leverage through which the shock acting on the road wheel is transmitted to the spring. Each spring 1 is pivoted to a carrier 3 in the form of a short internally screw-threaded tube which is engaged by an externally-threaded sleeve 4. The sleeve 4 can be rotated upon a radius rod 5. The forward end of the radius rod 5 is



pivoted to a lug 7 on the chassis, whilst its rear end is rigidly fixed to the back axle casing 9. The forward and rear ends of the spring 1 are connected to the chassis by shackles 10, 11, respectively. The spring 1 is moved bodily relatively to the chassis and radius rod in a longitudinal direction away from or towards the road wheels and back axle casing 9 according to the load to which the spring is to be subjected. This movement of the spring is effected by rotating the sleeve 4. The carrier 3 is thus caused to move axially upon the sleeve 4 either towards or away from the back axle. (*Accepted January 24, 1923.*)

191,482. The Villiers Engineering Company, Limited, Blakenhall, Wolverhampton, and F. Pountney, Penn. Brake Operating Mechanism. (2 *Figs.*) October 14, 1921.—The invention relates to brake operating mechanism for motor vehicles. According to the invention, an angularly movable sleeve K (which at one end carries the actuating pedal N and at the other end an arm L connecting with the brake B) is mounted upon a fixed spindle F extending through and supported



by ears H, H^2 carried by a fixed member (such as the engine plates of a motor cycle), and a transverse notch K^2 is formed in the wall of the sleeve K sufficiently deep to admit the ear H and to permit of so mounting the sleeve upon the spindle that it extends on each side of the ear. If desired, instead of notching the sleeve K, it may be made in two parts which are operatively connected by a bridge portion standing across the ear which divides the two parts from one another. (*Sealed.*)

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